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FOREWORD

The study, "Historical Trends Related to Weapon Lethality," was undertaken by the Historical Evaluation and Research Organization (HERO) in support of Project OREGON TRAIL, a study being conducted by the Advanced Tactics Project (AVTAC), Headquarters US Army Combat Developments Command, Fort Belvoir, Virginia.

The report contains the results of an examination and analysis of the relationship of weapons and military doctrine in history from the Fourth Century B.C. to the end of the Korean War. The substudy provided worthwhile contributions to Project OREGON TRAIL; it is considered to be of value to others.

The question of organizational and tactical trends related to weapon lethality is under continuing analysis in Project OREGON TRAIL. It may be expected that other substudies currently in progress, as well as the correlation of material gained in the conduct of war games, will provide further insight into this complex subject. Therefore, while the conclusions and recommendations of this study appear to be reasonable at the present stage of investigation, they should not be regarded as the conclusions and recommendations of Project OREGON TRAIL. The latter will be set forth in the Project OREGON TRAIL - Final Report.

T. R. [illegible]
Major General, US Army
Chairman, Advanced Tactics Project

Historical Evaluation and Research Organization
2233 Wisconsin Avenue, N. W.
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15 October 1964

SUMMARY

Final Report on

Historical Trends Related to Weapon Lethality

This report has been prepared for the Advanced Tactics Project of the US Army Combat Developments Command by the Historical Evaluation and Research Organization. It contains the results of an examination and analysis of the relationship of weapons and military doctrine in history from the 4th Century B.C. to the end of the Korean War. In noting the characteristics of the interplay among major elements of national power, the report identifies and examines each of the great advances in weapon lethality, considers their origins, relevant time lags in their application, and their impact on the balance of power. It suggests an approach to the quantification of lethality, deriving comparative lethality indices for major weapons, and suggesting a numerical relationship between lethality, mobility, and dispersion.

The report is accompanied and supported by three annexes, consolidating some 58 individual papers prepared in the process of the study. Annex I summarizes historical research on weapons and their interrelation with tactics and doctrine; Annex II deals with the technological background of advances in weaponry; and Annex III contains several analytic studies which were an important part of the effort.

The report first lists, defines, and tersely describes 18 significant advances in lethality, from the long Macedonian pike (c. 359 B.C.) to the atomic bomb (1945 A.D.). Attention then focusses on modern lethality advances of the 19th and 20th Centuries. Their attendant circumstances and their interrelation with tactics, organization, and doctrine are described. It is noted, for instance, that Napoleonic era weapons (flintlock, smoothbore musket, bayonet, and smoothbore muzzle-loading cannon) were compatible with contemporary tactics, of which the principal characteristic was the line of infantrymen,

shoulder to shoulder, and two or three files deep. The report then notes that in subsequent decades a series of innovations slowly but inevitably outmoded tactics, organization, and doctrine based upon the concept of this close, formal line of infantrymen. Most important of these were the greatly improved, accurate, long-range rifle of the 1850s, followed by the breech-loading rifle, the machine gun, the magazine rifle, quick-firing artillery, and high-explosive shell. The report notes that there were appreciable time lags between invention and adoption of each of these significant increases in lethality, and that they were not completely assimilated into doctrine until the concept of the combat team was introduced by the Germans in 1918. The report notes how further refinements in this concept, combined with the improvement of weapons, resulted again in compatability of weapons and tactics in World War II.

Analysis of this factual material is begun by examining the origins of major advances in lethality. The originators of new ideas and inventions are not divided significantly between military men and civilians, but rather between individual inventors, on the one hand, and a team, on the other, with significant increases tending more and more to be team efforts based upon the fundamental idea or ideas of individuals. France, Germany, Great Britain, and now the United States have been the sources of the significant advances.

The report distinguishes between (a) the invention or creation of a workable prototype, (b) the adoption of a weapon derived from the prototype, and (c) the assimilation of the weapon into an effective military system. Invention seems always to have been stimulated by experience in major hostilities, but accumulations of wartime stocks and understandably dated attitudes on the part of senior officers have tended to cause a time lag of 15 to 20 years between invention and adoption.

The report next examines the process of assimilation. Confident and effective employment of the weapon, and a drop in the user's casualties, are among the criteria for establishing the fact of assimilation of a change in lethality. Basic preconditions for assimilation have always included (1) imaginative, knowledgeable leadership; (2) effective coordination of national resources; and (3) an opportunity to evaluate combat experience. In the 20th Century, the second of these may be re-defined as the existence of a complex of research institutions and military staffs, which are intercommunicating and mutually supporting, and whose efforts are directed toward a common goal. The report suggests the desirability of efforts

to maintain the high leadership qualities essential to the first pre-condition by measures to stimulate and enhance military creativity. It also suggests the need for improvement of peacetime testing and evaluation procedures to establish a workable peacetime alternative to combat experience, which heretofore has been the third pre-condition of assimilation.

The report suggests that throughout history, save for the invention and demonstration of the atomic bomb in 1945, the invention of a weapon has not of itself affected the balance of power. This has been accomplished militarily only by novel tactical systems based on the imaginative use of new or modified weapons. The effectiveness of such tactical systems, themselves the outward expression of concepts, is much more apt to result from new ideas than from new weapons. Almost always, it has been new concepts, rather than new weapons, that have permitted inferior forces to overcome handicaps in numbers or equipment.

The report develops a basis for calculation of lethality indices for all weapons in history, from the hand-to-hand implements of antiquity to nuclear explosives. These lethality indices permit comparison of the effectiveness of weapons in terms consistent with historical experience. Use of these indices in relation to actual combat experience in four eras--the Napoleonic Wars, the Civil War, and World Wars I and II--has resulted in an expression of a quantitative relationship between lethality, mobility, and dispersion in combat.

The final chapter of the report concerns itself with the application of historical experience to current and future problems of war. It suggests that study of national and ethnic patterns of military behavior may permit us to strengthen greatly the combat effectiveness and morale of our own forces, and those of our allies, while simultaneously weakening the will of an enemy. Considering the problems of tactical nuclear war in historical perspective, the report notes that assimilation of tactical nuclear weapons into a viable military doctrine poses unprecedented difficulties. It suggests how the quantified relationship between lethality, mobility, and dispersion can be a useful tool in evaluation of current or proposed organizations and doctrine developed for tactical nuclear warfare. It emphasizes the need for attention to three important human factors which will be greatly affected by operations in a nuclear environment: morale, survivability, and leadership.

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HISTORICAL TRENDS RELATED TO WEAPON LETHALITY

A Report prepared for the Advanced Tactics Project of the Combat Developments Command, Headquarters US Army, under Contract No. DA 30-069-AMC-647(X), dated August 28, 1964

Historical Evaluation and Research Organization
2233 Wisconsin Avenue, N. W.
Washington 7, D. C.

15 October 1964

HISTORICAL TRENDS RELATED TO WEAPON LETHALITY

Table of Contents

List of Annexes

ANNEX VOLUME I--BASIC HISTORICAL STUDIES

ANNEX VOLUME II--SCIENCE, TECHNOLOGY, AND WEAPONS DEVELOPMENT IN HISTORY

Historical Trends Related to Weapon Lethality

INTRODUCTION

Purpose of the Study

This study of "Historical Trends Related to Weapon Lethality" has been undertaken for the Advanced Tactics Project (AVTAC) of the Army Combat Developments Command (CDC) by the Historical Evaluation and Research Organization (HERO). In essence, the study directive (reproduced in Appendix A) requires HERO:

(1) To derive from history the characteristics of the interplay among major elements of military power;

(2) To focus on cause, effect, and character of great advances in weapon lethality;

(3) To identify: (a) the origins of such advances, (b) the time lag between discovery of means and development of effective methods of employment, (c) the impact (if identifiable) on the existing balance of power;

(4) To ascertain, and to analyze similarly, instances in which new methods of operation have enhanced the lethality of existing weapons; and

(5) To quantify increases in lethality where possible, in terms of casualty rates, or ranges, or dispersion, or the like.

Rationale for Structure of Report

Informal authorization for HERO to perform this study was issued by AVTAC on May 15, 1964, and confirmed by a letter of intent from the Deputy Chairman of AVTAC. Because of its

relationship to a larger study being undertaken by AVTAC, a deadline of October 15, 1964, was set for submission of a report. Intensive work was begun on the study immediately; a Planning Conference, attended by most participants in the study, was held on May 22. A contract to perform the study was signed on August 27, by which time more than 90% of the work on the study had been completed.

Because of the shortness of time available for the study it has not been possible to pursue all possible avenues of research in this subject, and therefore we can not claim that this report is definitive. However, a thorough study has been made by HRRO of all the major innovations in weapons since the mid-6th Century B.C., ascertaining as completely as possible their influence on current tactics and organization at the time of their adoption. This material has been analyzed and the analysis reviewed by a number of members of the research team. The process of analysis has suggested further investigations which could be made, but time has not permitted more extensive exploration. It is unlikely that such efforts would effect major changes in the study conclusions.

In order to make this report as useful as possible to AVTAC, we have used a framework of presentation that could readily be expanded into a definitive study if funds were later made available for this purpose. For this reason, it might be appropriate to call this a "preliminary" study report, even though it is, of course, complete and final within the terms of the contract and of the original understandings between representatives of AVTAC and HRRO.

Scope and Content

It was decided at the outset to limit the scope and content of the study to significant increases in the lethality of weapons that directly affected the outcome of land combat. Some consideration has been given to related developments in naval and air warfare, particularly where these impinge directly on land operations, as is the case with the fighter-bomber and the amphibious landing team.

In assembling and reviewing relevant historical material dealing with weapons and tactics, the HRRO staff decided to divide history into three major eras: The Age of Muscle (from Antiquity to the mid-19th Century), the Age of Gunpowder (15th

Century through the 18th Century), and the Age of Technological Change (to include the 19th and 20th Centuries).

Two types of individual historical case studies were prepared for each of these three eras: (1) examinations of the development and perfection of important weapons, and (2) historical analyses of the interrelationship of weapon lethality with tactics, organization, and doctrine for all important tactical systems of history. The result was 38 individual historical case studies of varying lengths. In addition five topical studies were prepared to show the relationship between science and technology, on the one hand, and weapons development, on the other.

Analysis of these 43 separate historical studies was made in three different contexts. First were comparative analyses of effects of changes in weapon lethality on all issues relevant to the purpose of the study. A similar comparative analysis was made of the effects of changes in military organization and tactics on weapons development. Finally, a projection was made of the way in which lethality concepts could affect nuclear warfare. A total of 15 different analytical papers were prepared.

Thus, the basic background material from which this report has been prepared consists of some 58 different individual historical and analytical subetudies, which--because of the need for pressing ahead on a broad front to meet the over-all study deadline--perforce differ widely in treatment, style, scope, and length. To have reorganized, edited, and consolidated these into an integrated group of comparable papers of uniform treatment and character for this report would have required an effort in time, scope, and coordination which simply could not have been accomplished before the deadline. Since, however, the basic data was available in the historical papers, even though in different degrees of detail, it was possible for the HERO Permanent Staff to consolidate the historical studies into one, general, comprehensive annex, in which credit is given to each of the contributors. Somewhat the same kind of consolidation effort has been performed for the topical and analytical studies, although there was less need for achieving uniformity in style and format.

This report, therefore, is supported by three major annexes. Annex I (Basic Historical Studies) is a consolidation, in one coordinated, cohesive document of the 38 basic historical case studies on weapons and tactics. Annex II (Science, Technology, and Weapons Development in History) is a similar consolidation

of the individual case studies in this area. Annex III (Comparative Analysis of Historical Studies) performs the same function in presenting a number of the individual analytical studies in consolidated form. All of the individual studies themselves are available for reference purposes in the HERO Library and are listed separately in Appendix B.

This analysis has largely--although not completely--ignored Russian experience, both before and after the Russian Revolution of 1917. This was not a deliberate omission and calls for explanation. During Tsarist times the Russians attempted few fundamental military innovations; their technology did not begin to compare with those of Germany, France, and Britain. And while a number of lessons can be drawn from Russian experience in the Crimean, Russo-Turkish (1877-1878), Russo-Japanese, and First World Wars, most of these lessons are negative, or else merely duplicate or reinforce lessons of other wars more susceptible to research and analysis. As to Soviet experience, investigation of which we believe might prove more rewarding, information is both limited and scattered; more time would have been required for such investigation than would have been possible in the time available for this study. If any future extension of this study should be undertaken, we believe that time and opportunity should be provided for exploration of Russian experience.

Study Participants

Listed below are all participants in this study of "Historical Trends Relating to Weapon Lethality," including authors of individual studies, as well as those who have served in a consultant, review, or editorial capacity:

Orvil A. Anderson, Maj. General, USAF, Ret.; Special Consultant
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Riley Sunderland; HERO Staff Associate; Study Coordinator

Assistance in analysis and research was kindly given by Lt. Colonel William G. Stewart, USA, who permitted himself to be interviewed at length in regard to his study "Interaction of Firepower, Mobility, and Dispersion" (Military Review, March 1960).

Principal credit for successful completion of this study, and for the organization of this report and its annexes, is due to Mr. Riley Sunderland, Study Coordinator.

Despite HERO's gratitude for the splendidly cooperative efforts of all of the study participants, none of them, individually or collectively, can be held responsible for any portion of the report, or its annexes, other than as may be indicated specifically.

As Executive Director of HERO, the undersigned assumes full responsibility for the contents of this report and its annexes.

T. N. Dupuy
Executive Director

Washington, D. C.
15 October 1964

Chapter I

THE MAJOR ADVANCES IN LETHALITY

Interrelationship of Lethality and Combat Effectiveness

For the purposes of this study, the Advanced Tactics Project (AVTAC) has defined lethality as "the inherent capability of a given weapon to kill personnel or make materiel ineffective in a given period, where capability includes the factors of weapon range, rate of fire, accuracy, radius of effects, and battlefield mobility."[1] It is important to distinguish lethality from combat effectiveness, which has been assumed by this study to be the probability of obtaining a desired result in combat.

The inherent capability of a weapon is not a simple thing to assess. Various combinations of men and ideas applied to a given weapon may come successively closer to a full exploitation of that inherent capability, yet one can never be sure that a still better combination may not develop even more of the potential. Lethality, as defined by AVTAC, thus comprises a kind of mathematical limit, which can be approached ever more closely but which is never reached this side of infinity. Combat effectiveness, though somewhat easier to visualize, is even more difficult to measure, since it results from applying varying combinations of men, ideas, and weapons to different military situations.

The tank of 1916 was a relatively lethal weapon, yet in the hands of its users of 1916 it was not very effective. Poison gas was most effective in temporarily incapacitating individuals and units in combat in World War I. Yet only some 4% of those

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1. Letter dated July 24, 1964, from Maj. Gen. T. H. Lipscomb, USA, Chairman, AVTAC.

who breathed of it died, as against a corresponding figure of 23% mortality for US ground troops hit by weapon fire in World War I.[2] Gas was not highly lethal.

Moreover, lethality and combat effectiveness are not directly proportionate, although often parallel in relationship. Thus, the German Army and its supporting air arm in 1940 were so effective as to overrun France, Holland, and Belgium and force the British Expeditionary Forces off the continent, all within a space of six weeks. Yet Allied dead totaled only some 120,000.[3] In their great 1918 offensives, the Germans killed about 185,000 French troops, and killed, wounded, and captured 418,374 British: yet their offensives failed after gains measured in a few tens of miles.[4] Direct comparisons of this sort may be dangerously misleading unless parameters of comparison--to include considerations of time, space, and numbers--are established in advance.

Last of all, it must be noted that high casualty figures reflect not only the lethality of the weapon inflicting them but also the tactics employed on both sides. In the first day of the World War I Battle of the Somme the British advanced in carefully dressed lines, upright. At the end of that day they had lost 60,000 men killed, wounded, or prisoners. One of their divisions in two hours lost 218 of 300 officers and 5,274 enlisted men of 8,800 who had attacked.[5] The Germans had similar losses in some of their attacks on Verdun. Therefore, in discussing the major advances in lethality of weapons, it is necessary to go on to discuss the tactics and organization that most successfully exploited their lethality, and thus were most effective in combat. It is also necessary to consider the tactics employed by the

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2. The two figures are cited only to show the real difference between gas and other weapons as a killer, not as a basis for statistical comparison. The reader interested in the problem involved in the statistical analysis of combat mortality is referred to Gilbert W. Beebe and Michael E. De Bakey, Battle Casualties, Springfield, Illinois, 1952, Chapter III. The figure of 23% is from p. 74.

3. Ropp, War in the Modern World, p. 319.

4. Winston S. Churchill, The World Crisis, one vol. ed., New York, 1949. Based on tables A, B, and II.

5. Churchill, op. cit., p. 667.

other side to counter the lethal effects of the weapons. Such discussion also lays the basis for a consideration of the process by which major advances in lethality are assimilated into existing inventories of weapons, procedures, and ideas.

Advances in lethality in this study are considered primarily in terms of an informed judgment of the inherent capabilities of the weapon itself, rather than of the casualties it has inflicted. This approach seems justified, for example, because the relatively crude weapons of the American Civil War killed in action 21.3 men per 1,000 per year. The comparable figure for US soldiers in World War I was 12.0, and World War II, 9.0.[6] No one would argue, however, that the earlier weapons were more lethal; the difference in casualties lies in the adjustment of tactics to the inherent capabilities of contemporary weapons, dispersion being a major factor.

Definition of Major Advances

It now remains to define what this study means by referring to major advances in the lethality of weapons, and interrelated developments in tactics and organization. A major advance is one that changes the nature of warfare. It is a revolutionary change, which may be followed by a series of evolutionary changes, with which it should not be confused. Thus, the Maxim recoil-operated, belt-fed machine gun was a revolutionary weapon. Later machine guns were better weapons but have been part of an evolutionary process. Major advances of a revolutionary character may be made in tactics and organization when a new weapon is assimilated, or when a significant change is made in the employment of existing weapons. Thus, the German panzer division of the early days of World War II, which showed that the tank had been successfully assimilated, was a major advance.

The number of major advances in weapons and tactics in the course of history is relatively small. From the time when Philip of Macedon increased the lethality of the pike and then exploited its combat effectiveness by building the phalanx

6. Battle Casualties, op. cit., Table 4B. Deaths in action eliminates the medical question.

around it (c. 355 B.C.),[7] to the introduction of the atomic bomb, this study has recognized 18 significant developments in weapons and their lethality.

Listed below are these major advances in weapon lethality, with a brief statement of the significance of each. These are listed also in Appendix C on an analytical chart showing the processes of adoption and assimilation for each of these weapons, and indicating their relationship to some of the more important tactical systems of history.

As suggested above, it should be emphasized that the advances in lethality over the course of military history have not been due exclusively to weapons. Thus we note that there have been a number of ancillary technical developments affecting weapon lethality--of which individual armor would appear to be the first significant manifestation. Accordingly, in Appendix D we have listed 16 of those developments which we have considered most important in relationship to the advancement of weapon lethality, or weapon effectiveness. We have also prepared an analytical chart (Appendix E) to show when and how these developments have been adapted to military purposes, and the military systems to which they may have contributed. For cross-reference purposes, Appendix F is a brief summary of the major tactical systems of history referred to in Appendices C and E.

Major Advances in Weapon Lethality

Age of Muscle

1. Macedonian sarissa. Lengthened by order of King Philip shortly after 359 B.C. so that it was appreciably longer than contemporary pikes. It was used in the phalanx, an organization of 4,096 trained professionals, employed with outstanding successes by Philip and Alexander somewhat like a modern division.

2. Short sword. A heavy weapon, two feet long, the Roman short sword was adopted about 250 B.C., primarily to thrust into the vital organs, causing either instant death or fatal infection; its weight and breadth also permitted its use as a hand axe. Roman swordsmen were organized into small units of 120 men each,

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7. As suggested in Annex III-D, the process may have been inverted.

deployed in battle in a flexible formation that was prepared on short notice to move or fight at any point of the compass, with each soldier fighting as an individual, but so trained that by his efforts he was an element of a coordinated fighting machine. These units, plus light infantry and cavalry, formed a combat team, the legion, some 4,500 men strong, again roughly comparable to a modern division.

3. English longbow. Welsh hillmen before 1200 A.D.[8] apparently developed a longbow made of yew-wood that could be fired rapidly, and reputedly could drive its arrow through four inches of oak. But men had to train from childhood to use the weapon effectively. Although it was a significant increase in lethality over all other European hand-bows, it was in fact not much more inherently lethal than the slower firing, somewhat clumsy crossbow, which appeared in Europe about a century before the longbow was adopted by the English. The longbow was not significantly effective in combat until the English kings Edward I and his grandson Edward III, used longbowmen in great numbers to provide a base of fire for defensive-offensive tactics in which bowmen, light and heavy infantry, and small parties of elite armored cavalry operated in close and disciplined cooperation.

4. Mongol bow. This was a quite different kind of bow, of the reflex variety, and about as long as the English longbow, built up from horn and wood, and fired from horseback by men trained from childhood to ride and shoot. Grouped under the sophisticated command and control system developed by Jenghis Khan, guided by first-rate intelligence, and used in coordination with more heavily armored lancers, Mongol bows were significantly more effective than any weapons they met, and the Mongol forces were virtually invincible during most of the 13th Century.

Age of Gunpowder

Gunpowder by itself is merely a mildly dangerous explosive. It was known in Europe by 1250. It was 50 to 75 years before someone discovered how to make it lethal by confining and igniting it in an open-ended tube. The full assimilation of

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8. There is evidence that a full-scale prototype of the longbow existed in Egypt nearly 3,000 years before the Christian era. There is also some question of the Welsh origin of the English bow; it may have been developed in England.

gunpowder took nearly 400 more years, but by the middle of the 15th Century gunpowder weapons were clearly demonstrating a potentially significant increase in lethality.

5. The first cannon. By 1326 A.D. gunpowder was being used to hurl small missiles at castle gates. The device it was fired from, however crude, was a cannon and made gunpowder lethal. It was, therefore, the fundamental jump to lethality for gunpowder.

6. Arquebus. About 120 years later, the first reliable hand-gun was invented. From it the matchlock arquebus was developed by the middle of the 15th Century. Its slow rate of fire offered real problems to the user, who was both ineffective and defenseless while reloading. Solution of these problems was sought in a combination of (a) protecting the vulnerable arquebusier by formations of pikemen and (b) having arquebusiers form in files ten deep to fire in turn, each man countermarching to the rear to reload. This tactical solution was best exemplified in the so-called "Spanish square" (early 1500s).

7. Weapon improvements of Gustavus Adolphus. The improved and more lethal weapons introduced by this king were a major element in his generally reformed military system, whose tactical and organizational changes were the foundation of European military practice for the next three centuries. By issuing cartridges (first large scale employment of an idea developed much earlier) he sharply increased the rate of fire of musket and cannon. To exploit increased infantry firepower he initiated linear tactics by forming his soldiers in a shallow line rather than the relatively deep mass of the Spanish square. To exploit increased artillery firepower he lightened tubes and carriages, and improved artillery organization, providing a significant increase in tactical mobility and efficiency over previous contemporary practice.

8. Flintlock and bayonet. This combined a simpler, more reliable gun with a hand-to-hand weapon that made the gun lethal even after it had been fired. Introduction of the ring bayonet ended the long transitional period in gunpowder, since pikemen were no longer needed to protect the soldier with an unloaded gun. Becoming general in Europe about 1700, this combination remained standard until well into the next century, i.e., about 125 years. Linear tactics and smoothbore cannon were perfectly matched to the inherent lethality of the flintlock and bayonet.

Age of Technological Change

The weapons of this period as a group constitute a quantum jump in lethality over their predecessors of the Age of Gunpowder. Since they were introduced in relatively modern times, with better records available, the circumstances of their invention and of related developments are much clearer and lend themselves more readily to analysis.

9. Long-range, high-velocity rifle bullet (1849). Known commonly as the Minié ball, this conoidal projectile, fired from a muzzle-loading rifle that was discharged by a weather-proof percussion cap, had an effective range equal to that of contemporary smoothbore cannon and was considerably more accurate than the old flintlock. The primary infantry weapon of the American Civil War, it caused most of the casualties in that war and initiated a revolutionary readjustment in infantry tactics. The adjustment, however, proceeded comparatively slowly.

10. Breech-loading rifles (1848). By permitting the user to lie prone while firing and loading, they made the muzzle-loader obsolete. The idea was not new, and workable prototypes had been in use more than a century earlier. Mass adoption for all infantry came first in the Prussian army in 1848, although the "needle gun" was not unveiled until the Danish War of 1864.

11. Breech-loading rifled artillery (1845-1846). This is the date of the first workable prototypes. They were not widely used, however, for 25 years. After steady improvement they revealed themselves in the Franco-Prussian War (in German hands) as clearly superior to the old-style French muzzle-loaders. Sharply increased range and rate of fire made them significantly more lethal.

12. Maxim machine gun (1883). This belt-fed, recoil-operated weapon is the prototype of modern automatic weapons. In World War I the machine gun proved to be one of the most significant of all advances in lethality since the introduction of gunpowder.

13. High-explosive shell (1886). Light artillery shells filled with high explosive would produce rather more than 1,000 lethal fragments 20 feet from the point of burst. The old black powder shell of the American Civil War produced only from two to five fragments; Prussian shells in the Franco-Prussian War broke

into as many as 30 fragments. Thus on fragmentation alone, high-explosive shell was theoretically 150-200 times as lethal as black-powder shell.

14. Bolt-operated magazine rifle (c. 1895). There had been numerous magazine rifles in various armies for nearly half a century, but the vastly improved Mauser became the prototype of the standard infantry rifle of the world's armies on into World War II. The principal factor increasing lethality was greatly increased rate of fire. Outstanding was the American Springfield, M1903. Largely for financial reasons these rifles were slow in being superseded by the semiautomatic rifle, nearly half a century later.

15. Tank (1916). The internal combustion engine driving an endless track made it possible to give cross-country mobility and armor protection to machine guns and light cannon. This made them significantly more lethal than unprotected horse-drawn or man-carried weapons. The tank was a mechanical step toward solving the tactical stalemate created in World War I by the recent previous advances in lethality.

16. Fighter-bomber (1917). This aircraft introduced new dimensions of flexibility, range, and reaction time to the problem of putting a relatively large projectile (or machine-gun bullets) on a point target. (Also note that medium and heavy bombers could be used on the battlefield on an ad hoc basis. The German Stuka dive-bomber was a briefly successful freak early in World War II, rather than a significant increase in lethality, because the environment could be made too effectively hostile to it.)

17. Ballistic missile (1944). By its range, all-weather capability, and relative imperviousness to countermeasures, this German invention[9] (unveiled in 1944) greatly increased the lethality of its warhead. It was the prototype of a whole family to which tactics and organization are still responding and--if only because of its quantum jump in range--constituted a significant increase in lethality.

18. Atomic bomb (1945). In part because its first use in strategic bombardment was universally publicized, and its lethality generally appreciated, this weapon has been unique in

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9. Based largely upon theoretical rocket developments pioneered by an American, Robert H. Goddard (1882-1945).

forcing changes in tactics and organisation even though it has never been used tactically in battle. The adequacy of responses to nuclear weapons is perhaps the most serious military problem of this, or any previous age.

Chapter II

SIGNIFICANT TACTICAL CHANGES SINCE 1815

By the close of the Napoleonic Wars, the dominant weapons of the battlefield were the combination of flintlock and bayonet, supported by smoothbore, muzzle-loading cannon. Cannon had marked superiority in range over the flintlock, and probably inflicted nearly half the casualties in combat. In battle, armies formed in line to defend, or to attack by fire, and usually formed in greater depth (the so-called "column") to ch... This tactical system by 1830 was about 200 years old. Until the Napoleonic era, the proportion of casualties (killed and wounded) to total effective forces under the linear system had declined steadily from 15% for victors and 30% for losers in battle in the Thirty Years' War to about 9% and 16% respectively during the French Revolutionary Wars. Napoleon's later insistence on--or tolerance of--columnar attacks without thorough preparation drove the casualty rates up sharply to 15% and 20%. In the several minor wars fought under the system after Napoleon, casualty rates fell even below those of the French Revolutionary period. This would suggest that a balance had been struck between the lethality of weapons used and the combat effectiveness of linear tactics by men so armed.

The Mexican War was the last fought by the US Army with smoothbore muskets and linear tactics against a similar doctrine. Casualty experience there began a significant century:[10]

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10. Gilbert W. Beebe and Michael E. De Bakey, Battle Casualties, Springfield, Illinois, 1952. Table 4. Note, these are annual figures, and not single battle figures, as discussed above. Note also, these do not include wounded, usually about 3.5 times as numerous as those killed in action.

Name of War	Killed in Action per 1,000 per year
Mexican War	9.9
Civil War	
North	21.3
South	(loss data incomplete)[11]
Spanish War	1.9
Philippine Insurrection	2.2
World War I	12.0
World War II	9.0

In 1858, the United States adopted the conoidal bullet, fired from a muzzle-loading rifle-musket. This was the standard weapon used by North and South in the Civil War, and it was lethal at longer ranges than canister or spherical case shot fired from contemporary cannon. Solid shot and shell from smoothbore cannon could reach as far as the conoidal bullet from the rifle-musket. But contemporary shells, if they burst, broke into only two to five fragments, while direct hits with solid-shot cannon were extremely rare. In short, the relation of lethal capability between infantry weapons and artillery had been reversed. As a result, of a sample group of 144,000 Civil War casualties the causes were:

Conoidal rifle bullet	108,000
Smoothbore musket, round ball	16,000
Shell fragments	12,000
Canister, grape, and cannon ball	399
Explosive bullets	199
Edged weapons (mostly sabers)	7,000
	144,000

In summary, small arms (mostly rifles) caused 86% of the casualties, cannon caused 9%, and edged weapons caused 5%.

Both sides used linear tactics during the Civil War. On many occasions, most notably when fighting over broken ground, troops would spontaneously break into little groups and fight from one cover to another. But to attack or defend, men would be formed in lines of two or three ranks; to weight an attack, one regimental line would follow another to make a great column, as in Napoleon's day. The resulting imbalance between infantry

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11. But generally greater than Union loss figures; see Thomas L. Livermore, Numbers and Losses in the Civil War, University of Indiana, 1957, reprint.

weapons of greater potential lethality, on the one hand, and tactics better suited to the weapons of a previous generation, on the other, sent casualties on both sides soaring to levels comparable to Napoleon's bloodiest battles. By the end of the war, however, there was a clear, although slow, trend toward dispersal.

From 1866 on in western Europe breech-loading rifles were standard issue. The increased rate of fire seems to have compensated for the increase in the capabilities of field artillery which resulted from the slightly later introduction of breech-loading and rifling in cannon. Thus, in the Franco-Prussian War as in the Civil War, casualties from rifle bullets were about ten times those from artillery. It does not appear that the implications of this fact were appreciated initially in the Prussian or French services any more than they had been by either North or South in the American Civil War. Adaptation to the new situation came somewhat more rapidly in the Prussian Army, perhaps, but even at the end of the Franco-Prussian War, the linear tactics of Gustavus Adolphus were still in vogue.

Appreciation of the impact of the significant increase in lethality of infantry weapons resulting from rifling and breech-loading was first shown when the Prussians dropped the close-order bayonet charge from their tactics. And Prussian combat formations spread out into "open order," so that all infantrymen acted as skirmishers, much as had been the unofficial practice in America a few years earlier, at the end of the Civil War. The difference, however, lay in the fact that the Germans studied the lessons of their 19th Century wars--reinforced by observation of the Russo-Japanese War--more intently, and with better results, than their contemporaries.

As of 1914, there had been no general impact on military practices from the greatly increased lethality of modern artillery (with recoil system, breech-loading, rifling, and particularly high-explosive shell), of breech-loading magazine infantry rifles, or, above all, of the machine gun. The experiences of the Russo-Japanese War--which should have provided warning--were largely ignored. There were, however, some efforts to cope with the new weapons, and a wide disparity of practice existed. The German Army preferred a combination of strategic offensive and tactical defensive. The latter made effective use of machine gun and high-explosive shell, but German organization, and tactics on the offensive, were still not very different from those of 1870. The British had not looked beyond a small force of superbly trained riflemen on the flank of the French Army. The French--imbued with a dedication to the moral value of the

offensive--had completely misread the situation and made no adaptation of their infantry tactics because of automatic weapons and high-explosive shell, although they had devoted much attention to improving the quality of their artillery.

As a result of only partial recognition by the Germans of the defensive power of the combination of earthworks, machine guns, and high-explosive shell, and the even greater lack of comprehension by their Allied opposite numbers, there was a tactical stalemate on the Western Front for three years. Political and strategic pressures interacted with this incomprehension to cause five major Allied offensives to the Germans' one; all relied primarily on frontal assault behind massive artillery barrages. Allied casualties were astronomical, with little to show for them, although German losses were also very heavy.

Both sides sought ways to end the stalemate and to cut the cost of the unsuccessful efforts to break it. The Franco-British solution was at first simply mechanical: the tank. Their decision-makers were willing to add the tank to their inventory, but not to change tactics, doctrine, or organization. The Germans decided to change tactics, organization, and doctrine, but missed the potential importance of the tank.

In fairly rapid succession the Germans introduced first the triangular division, and then combat teams built around a base of fire and a maneuvering element, and acting in tactical independence but strategic coordination. In using machine guns and mortars for an offensive base of fire, this system was the first fully to assimilate automatic weapons and high-explosive. These tactics were able to overcome the Allied defenses, and in 1918 to make major breakthroughs--which, however, their logistics could not support. The importance of these new tactical developments was recognized by the Allied side, and they were applied in turn by them, with the added advantage of the tank, which fitted perfectly with the new tactics.

The lessons of 1918 were subsequently examined by all Great Powers; but Germany, with a thorough research effort into past experience and current technological advances, backed by adequate financial support from the government, made much more effective advances between the wars. Basing their new tactical system upon the infantry combat team concept they had developed in 1917-1918, the German military planners elaborated the concept by using armor in mass (while teaming subunits of armor with subunits of infantry), and by providing radically improved tactical air support to supplement and (if necessary in mobile warfare) supplant

artillery. A flexible, decentralized, command system permitted taking full advantage of the flexibility of such combinations. With this doctrine, the tank and the fighter-bomber may be said to have been fully assimilated into land warfare.

Following the German innovations of 1918, infantry deployments opened up for the third time since the handgun first became an effective weapon on the battlefield.[12] The line was now replaced by small teams of men, combining firepower in terms of air and artillery support. Making full use of surprise, cover, and tactical mobility, the teams could saturate a small portion of the defense system with fire, exploiting the defense's problems of judgment and reaction time by a combination of mass (essentially massed firepower) and maneuver.

These new infantry concepts, pioneered by the Germans in 1918, and brought to full development by integration with armor and air in their blitzkrieg tactics of 1939-1940, were not materially changed during the course of World War II. They were embellished and modified to some extent in the two principal varieties of interservice task force operations which contributed materially to final Allied victory in the war. The first of these was an Anglo-American adaptation of German pioneering airborne efforts. The second was the Anglo-American perfection of amphibious assault techniques. Fundamentally, however, despite a considerable amount of independent and parallel development, these interservice task force concepts were technical adaptations of the basic German combat team tactics.

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12. The previous times having been: (1) the linear system of Gustavus Adolphus and (2) the gradual dispersal forced by firepower in the Civil War, Franco-Prussian War, and Russo-Japanese War, without, however, changing linear concepts.

Chapter III

ORIGINS OF MAJOR ADVANCES IN LETHALITY

Basis of Analysis

The analytic portion of this study is primarily based on developments in modern times, beginning with first steps away from the old flintlock, in the 1830s. In earlier days, creating major advances in lethality and assimilating them was the work of individuals, whose appearance was in large measure a matter of accident. With the 19th Century, industrial, military, research, and administrative institutions began to emerge in the several Great Powers of Europe and in North America which could exploit the "greatest invention of the Nineteenth Century . . . the invention of the method of invention."[13]

New interest in research, and communication between various institutions engaged in it, made it possible for military thinkers, as never before, to take advantage of the scientific and technological changes that began to come ever faster. Thus, beginning in the mid-19th Century major advances in weapons lethality and in tactics and organizations which could best exploit them were closely linked with changes in science and technology, although for much of the century military developments lagged far behind.

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13. Alfred North Whitehead, Science and the Modern World, New York, 1948, p. 141.

Time of Origin of Major Advances in Lethality Since 1830

The dates of origin of the significant advances of the Age of Technological Innovation are curiously bunched. The conoidal rifle bullet, an effective breech-loading rifle, and breech-loading rifled field artillery appeared between 1841 and 1849. The modern machine gun, the high-explosive shell, the Mauser bolt-operated magazine rifle, smokeless powder and quick-firing modern artillery appeared between 1883 and the mid-1890s. The tank and fighter bomber appeared in a two-year period, 1916-1917. Atom bomb and ballistic missile were introduced within a year of each other in World War II.

The first two groups of significant advances noted above were conceived in peacetime. Noteworthy progress was apparent for an item of each group about 15 years after the end of previous major hostilities. Workable models of all appeared in a group, as noted above. The explanation may be that major wars have left both budgetary problems and a sort of apathy in their wake, which take an appreciable amount of time, on the order of 15 years, to disappear. Then people with time to think begin to produce changes in established practice on the basis of wartime experience. How long it took armed services to purchase these developments and then to assimilate them, is another problem, to be considered below.

The latter two groups of increases in lethality (tank and fighter-bomber, ballistic missile and atomic bomb) were wartime developments. In each case, the basic concept originated in peacetime but the impetus to develop the device was lacking until national danger supplied both the overriding need and the resources. The Austro-Hungarian Army of 1911 turned down a workable tank; it is certain that the US Congress of the inter-war years would not have voted billions for the MANHATTAN Project.

Identity of Originators

If one considers from what types of individuals significant increases in lethality have come, the lines of division seem to fall not between military and civilian, but between individuals and groups, and between private agencies and

government. Both the types of weapons and the period in time seem to be important in drawing the lines. In general, the men associated with the development of small arms were civilians, and worked essentially as individuals, although there were a significant number of military men involved as well. Because of the foundries, laboratories, and metal-working machines required, major developments in artillery and its ammunition were sponsored by private manufacturers in Great Britain and government arsenals in France and Germany. The actual inventions affecting artillery and ammunition are to a large extent--but not exclusively--associated with the work of civilian technicians and chemists, mostly in the large private or government manufactories.

Up to 1900, the principal problems involved in gunpowder weapons had been those of weight, smoke, recoil, rate of fire, range, fusing, fragmentation, and accuracy.[14] These problems were centuries old and well-known. There seems to have been no case of a government's placing a requirement that any of these weapon deficiencies be solved. When advancing technology offered the possibility of a solution some individual would eventually see the opportunity, would create something, and then offer it to the government. The role of government arsenals in this process was distinctly minor, limited to a few artillery developments. The classic picture was that of the inventor trying to sell his new discovery to a government agency. That a government agency should ask inventors to produce new and more lethal weapons is decidedly new.

In World War I the process of originating significant increases began to change. As a result, while aircraft, the tank, ballistic missiles, and the atomic bomb all trace their origins to the basic concept of an individual civilian, in each case they were made into weapons through major effort of one or more government agencies, with both military and civilian participation. The shift was from small private industry to large governmental agency. That is, up to 1914, a private person or firm would have seen opportunity or need and done something about it. Beginning with the idea of a track-laying armored vehicle in the fall of 191[illegible] the subsequent process has largely

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14. The major problem of obturation--or sealing a breech-loading weapon--had been solved earlier by the introduction of self-contained, metal-cased cartridges.

(but not entirely) been for someone in government to see a need to get enough support from his superiors, and to initiate a process that results in placing demands on private industry. Both military and civilians are usually involved at every stage.

By nation, most of the pre-1914 innovations divide almost evenly among the three industrialised Great Powers: France, Germany, and Great Britain. Hiram Maxim, the inventor of the modern machine gun, was an American, but it is significant of the temper of the times in the United States that he moved to Great Britain and did his work there in connection with the great Vickers arms manufactory. These three powers, very conscious of their need for effective arms, possessed of advanced technologies, and with relatively ample budgets, offered the best prospects to inventors and manufacturers. After 1917, the United States joined this group and has since taken the lead.

Stages in Introducing Major Advances in Lethality

In every case, the idea of an advance came far ahead of the development of a workable device. For instance, Leonardo da Vinci thought of the tank and the airplane some 490 years before they could be built. Experiments were tried with breech-loading cannon and explosive shell in the same period.

With the coming of the Industrial Revolution it became possible to build all of these innovations and then to improve significantly upon them. The interval from concept to prototype to item of issue also shrank progressively in keeping with the ever faster rate of technological progress. Thus, from the first breech-loading cannon to a safe, practical model, took at least 400 years. From this cannon to the "French 75" took 51 years. From the first flight of a tiny model aircraft in 1795 to the Wright Brothers' man-carrying model in 1903 the interval was 108 years, and from then to the fighter bomber in 1917 another 14. Technology now provides a stock of knowledge that permits a faster and--thus far--accelerating translation of the idea for a weapon into the thing itself.

Chapter IV

THE ASSIMILATION OF SIGNIFICANT ADVANCES IN LETHALITY

It is necessary to distinguish clearly among: (1) making a workable prototype weapon that marks a significant increase in lethality; (2) its adoption by armed forces; and (3) its assimilation, i.e., adequate reflection of its capabilities in tactics, doctrine, and organization.

Adoption: The First Step Toward Assimilation

The invention of a workable weapon that can provide for a significant increase in lethality has not in the past guaranteed either that it will be promptly purchased by any armed force or that if bought it will be purchased in sufficient quantity to be standard issue. British Major Patrick Ferguson, invented a serviceable breech-loading rifle in 1776.[15] Some 80 years later the Union bought enough repeating breechloaders to equip a portion of its forces, but for the most part fought the war with single-shot muzzle loaders. Not until the Seven Weeks' War in 1866 was the muzzle-loader really superseded.

The interval between invention and adoption reflects several things. It must be borne in mind that man is not everywhere and at all times at war; industry, commerce, law, medicine, and engineering are continuous. New devices and new ideas in these latter fields can be tried out at any time. Competition is present. In sharp contrast, wars have sometimes occurred at very long intervals, and before 1914 there were several such intervals. Thus, a French officer commissioned in 1872 at 21 years of age

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15. Both the French and Austrian armies had experimented with breech-loading musket carbines as much as 50 years earlier.

would have been 63, almost at the end of his career, before he faced a European enemy in 1914. This is not the case in other professions, nor with other institutions. Only armed forces can go for more than a generation with no practical test of what they have been learning, teaching, practicing, and buying.

Next it must be remembered that major wars leave behind two legacies: (1) budgetary problems and (2) large stocks of material. The budgetary problems put pressure on the armed forces to use up the inherited wartime stocks. (Here it may be suggested that the Allies of World War I did the German Army a real service in forcing it to scrap the materiel of 1918.) These budgetary problems, these masses of obsolescent materiel, suggest why the first of two groups of significant advances in lethality prior to 1914 followed about 15-20 years after the Napoleonic Wars and the second followed a similar period after the American Civil and Franco-Prussian Wars.

Another and very important reason for this delay is that the generation of the previous war, which was accustomed to and made its careers with this older materiel and the ideas associated with it, had to leave positions of authority before new ideas could have an impact. In this connection, a great physicist observed: " . . . new scientific truth does not triumph by convincing its opponents . . . but rather because its opponents eventually die [or pass from power] and a new generation grows up which is familiar with it."[16]

The above considerations apply everywhere; there are no clear patterns of national behavior in regard to adopting weapons. Instances can be found where national problems or practices caused a power to lag in adopting a certain weapon, but these are cases, not patterns. The Russians stressed the bayonet and lagged in adopting the machine gun; the Germans stressed the machine gun and lagged in adopting the tank--which the British had invented to counter German machine guns. To draw conclusions about national behavior from these cases is impossible.

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16. Max Planck, Scientific Autobiography and Other Papers, trans. F. Gaynor, New York, 1949, pp. 33-34, quoted in Thomas S. Kuhn, The Structure of Scientific Revolutions, Chicago, 1962, p. 150.

Interval Between Adoption and Effective Use

It has always taken a while for a weapon to become a fully contributing member of the current arsenal of weapons, i.e., to be used in a way that capitalized to the greatest possible extent on its characteristics and potentialities. This is to a considerable degree necessary, as experimentation is ordinarily required with any new device to see how it will perform best. This time lag is further influenced by the current mode of thinking, which invariably tends to try to fit a new weapon into existing tactics, and changes the tactics later only as it becomes apparent that the new weapon permits, or demands, such changes.

This is clearly shown in the case of the arquebus, the first handgun that was sufficiently perfected to be adopted on a large scale. It was adopted generally in the second half of the 16th Century. But it was first used in the manner of fighting which was usual at the time, by massed infantry, firing in volley. In this fashion the men firing the weapon were defenseless and able to contribute nothing to the battle during the long period of time which it took to reload the arquebus. It was some 50 years before the device of the countermarch was developed, so that the men in the first rank of files of ten fired, then moved to the rear of the line to reload while successive ranks followed the same procedure.

This was the first effective solution of the use of individual gunpowder weapons in combat. From then on, other types of handguns could be used on the battlefield practically as soon as they were invented. It does not follow, however, that this initial use was their most effective use; in general there was a period of experimentation of 20 to 30 years. The same was true of the first radical changes in artillery weapons, late in the 19th Century. The uses of both tank and combat aircraft were postulated before or with their introduction in combat; the problem with each was that of properly exploiting their inherent lethality. The ballistic missile from the first has been used essentially as long-range artillery, but again assimilation has been slow. Nuclear weapons have offered tactical difficulties of a conceptual nature comparable to those which affected the introduction of effective gunpowder small arms; at present there seems to be no reason to think that assimilation will be any easier or quicker.

The lapse between invention and demonstration of a weapon and the settling upon its application in battle was apparent at

the outset in regard to the atom bomb. The first two were used in 1945 as weapons of mass destruction or terror. By the time of the Berlin blockade of 1948 the United States still had evolved neither policy, tactics, nor doctrine for tactical use of nuclear weapons in ground combat. Indeed the first major attempts to consider changes in Army tactics, doctrine, and organization were not made till the next year, 1949. The United States did not use such weapons in the Korean War, 1950-1953, nor were they used by the enemy. Those studies of the use of tactical atomic weapons that were made were highly classified but evidently failed to produce the tactical rationale which might have been reflected in open literature. Discussions of the topic appearing in contemporary unclassified literature reveal emotional and political pressures, weighing on any attempt to assimilate tactical nuclear weapons, highly reminiscent of the early days of gunpowder. As of the terminal date considered by this study (1953) the process of assimilating nuclear weapons had just begun and was proceeding under severe handicaps.

The Process of Assimilation of New Weapons and New Concepts

Before attempting an analysis of the process of assimilation, it will be helpful to make clear the distinction we make between military creativity and assimilation. In this study we have considered that military creativity is the ability to develop or generate new things (weapons and equipment), new ideas, and new ways of relating things to ideas. Assimilation is the process whereby new things or new ideas are made compatible with existing situations, organizations, and attitudes, so that these new entities are employed as effectively as the mores and technological development of the times will permit. Thus, to a substantial degree, creativity is essential and basic to assimilation, but creativity does not automatically assure assimilation.

Neither military creativity nor assimilation can be considered in a vacuum, but must be related to the processes of change and of adaptation of society as a whole. Because new military developments have appeared with increasing frequency since just before the middle of the 19th Century, and because armies have subsequently become progressively more sophisticated and complex, it might not be unreasonable to assume that both the processes of military innovation and military assimilation have improved and accelerated in this recent period. Our present

study, however, would suggest that this is not so. Society as a whole has been undergoing dramatic changes following the near-simultaneous appearance of the French and Industrial Revolutions, and unquestionably this process of technological and social change has been accelerating. It appears, however, that military innovation and assimilation lagged somewhat during much of the Industrial Revolution and may not yet have caught up with the fast pace of change in society as a whole.

As suggested above, this study assumes that the assimilation of a new weapon is the process whereby the employment of the weapon is made compatible with existing situations, organizations, or attitudes so that its capabilities are adequately reflected in tactics, organization, and doctrine--or, in other words, when its capabilities are used to the greatest possible extent and its limitations minimized. It is relatively easy to ascertain from observation, or from the record, when a weapon is not assimilated; it is almost as easy to find a time when the weapon has been assimilated; it is less easy to ascertain exactly when the assimilative process is accomplished.

When a radically new weapon appears and is first adopted, it is by nature incongruous with existing weapons and doctrine. This is reflected in a number of ways: uncertainty and hesitation in coordination of the new weapon; inability to use it consistently, effectively, and flexibly in offensive action, often leading to tactical stalemate; vulnerability of the weapon and of its users to hostile countermeasures; heavy losses incident to the employment of the new weapon, or in attempting to oppose it in combat. From this it is possible to establish the criteria of assimilation as follows:

a. Confident employment of the weapon in accordance with a doctrine which assures its coordination with other weapons in a manner compatible with the characteristics of each.

b. Consistently effective, flexible use of the weapon in offensive warfare, permitting full employment of the advantages of superior leadership and/or superior resources.

c. Capability of dealing effectively with anticipated and unanticipated countermeasures.

d. Sharp decline in casualties for those employing the weapon, often combined with a capability for inflicting disproportionately heavy losses on the enemy.

Appendices C and E provide information regarding the adoption and assimilation of weapons of greatly increased lethality, and the application of significant ancillary technological developments which have to a significant degree directly or indirectly enhanced, or contributed to, the lethality of weapons. These appendices suggest the following hypotheses regarding the assimilation of weapons of the past:

1. There have been three basic preconditions historically for assimilation of new weapons or ideas:

a. An imaginative, knowledgeable leadership focussed on military affairs, supported by extensive knowledge of, and competence in, the nature and background of the existing military system.

b. Effective coordination of the nation's economic, technological-scientific, and military resources.

c. Opportunity for battlefield experimentation as a basis for evaluation and analysis.

2. When these conditions have been present, there has usually been a time lag of approximately 20 years, or one generation, between the initial, experimental adoption of a new weapon and its full assimilation. It is notable that this time lag does not seem to have changed much over the course of the past century, despite the fact that science and technology have been producing new weapons, or adaptations of weapons, in accelerating numbers. When the conditions have not been present (which was frequently the case before 1830) the process of assimilation has been slower.

3. New weapons, or modifications of new weapons, have generally been developed because scientists, technicians, or soldiers have perceived an opportunity to develop a new weapon or improve an existing one. Only rarely in the past have new weapons been designed for the specific purpose of coping with a tactical problem.

4. There has been a natural reluctance to make a sweeping change in tactics, or organization, by widespread adoption of a new and untried weapon before it has been thoroughly investigated under battle conditions. There is some evidence (not conclusive) that intelligent boldness in this respect can pay handsome dividends (as the Prussian adoption of the needle gun). Despite this reluctance and despite the likelihood that optimum assimilation

will be impossible without battlefield testing, the increasing pace of invention is placing pressures on the military today to make such sweeping changes.

5. The substantial leadership in military affairs enjoyed by Prussia, and then Germany, over a period of about a century (c. 1840-1942) did not stem from any inherent intellectual, scientific, or fighting superiority on the part of the Germans. Rather it stemmed from their earlier realization of the significance of the impact of the Industrial Revolution on warfare in terms of increased complexity in weapons and of the methods of employing them. Thus, much earlier than other nations, the Prussians so organized themselves as to acquire systematically, and without dependence upon chance, the kinds of competence indicated in the first and second preconditions for assimilation of weapons (items 1-a and b, above), and this systematic organization also permitted them to exploit fully and promptly their own battlefield experimentation and that of others. The initial advantage resulting from this systematic organization of German military affairs, exemplified by their Army Great General Staff,[17] persisted at least to 1942.

From this German example, and those of the other great powers who have followed the German pioneering work in general staff concepts and in relating military affairs to national society as a whole, it is possible to refine for the mid-20th Century the second of the three hypotheses regarding preconditions of assimilation as follows:

a. There must exist industrial or developmental research institutions, basic research institutions, military staffs and their supporting institutions, together with administrative arrangements for linking these with one another and with the top decision-making echelons of government.

b. These bodies must conduct their research, developmental, and testing activities by mutually familiar methods so that their personnel can communicate, can be mutually supporting, and can evaluate each other's results.

c. The efforts of these institutions--in related matters--must be directed toward a common goal.

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17. It should be noted that this was never an interservice general staff, in any way comparable to the current US Joint Staff.

It is evident that the process of systematic development of new and more lethal methods of warfare is a very expensive one. Thus it is important to assure maximum efficiency in the coordination of the efforts of the institutions concerned and in the procedures followed within the institutions. Our investigation indicates that this effort can benefit by use of mathematical tools of management analysis and control. (See Annex III-F.)

What is <u>not</u> yet clear is whether our new methods of peacetime experimentation--through sophisticated wargames, computerised evaluations, and the like--are in fact sufficiently realistic to provide adequate substitutes for battlefield experimentation (the third precondition). There is good reason to believe that, at present, they are <u>not</u>.

More useful, perhaps are attempts to recreate in peacetime the test of combat under physical conditions that simulate war as closely as possible and that also permit study. We have reason to believe that such attempts, as at the Combat Development Experimental Center at Fort Ord, have been useful, but still inherently lack the physical and psychological elements of conflict, risk, and destructiveness which are the essential elements of combat, and without which there can be no real combat trial.

It has been brought to our attention, however, that the Institute for Defense Analyses has recently successfully investigated engineering methods of integrating two previously unrelated technological testing methods which might permit actual recreation of combat conditions for testing weapons and tactics, at least on a limited scale. This investigation, as we understand it, has been the marrying of the most recent methods of individual television surveillance and of the remote handling of radioactive materials, to permit actual projection through "telefactor" of an individual's intelligence and reactions to control of objects in space through television and telemetry. The production of a workable prototype is anticipated within two years.[18] If the system works as envisaged (and there appears to be no scientific or engineering reason why it cannot), it could be applied to the testing under full combat conditions of opposed

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18. A report on this matter can be expected from the Institute for Defense Analyses shortly after November 1, 1964. Contact at IDA is Mr. William Bradley, Deputy Director of Research, who instigated an intensive investigation of this matter in a 1964 IDA Summer Study.

weapons or weapon systems, tank against tank or antitank weapon, aircraft against other aircraft or antiaircraft defenses, etc. Even broader applications may soon be possible to permit, for the first time in history, actual armed conflict between human opponents, with no limitations on effects of weapons, without danger to human life. The significance of this to tactical development is obvious, in light of the preceding discussion. The possible combat application of the "telefactor" concept is perhaps more fascinating, but beyond the scope of this study.

Chapter V

CONCEPTUAL ASPECTS OF WEAPON LETHALITY

Weapons, Tactics, and the Balance of Power

Until very recently there had been no instance in history in which a new weapon, by its very lethality, has been able to affect the international balance of power. There are, of course, numerous examples in which a new tactical system, based upon the assimilation of a weapon or group of weapons, has changed the balance of power, at least temporarily. In this study we have noted, for instance, such tactical systems as the Macedonian phalanx, the Roman legion, the Mongol touman, the English "battle," the linear system of Gustavus Adolphus, the Prussian battalion of Frederick the Great, and most recently the German blitzkrieg combination, all of which were based upon the imaginative utilization of new or radically modified weapons, and all of which directly affected the world balance of power. It is significant, furthermore, that there was in each instance a substantial time lag between the appearance of the new weapon and its application in the new system in such a way as to change the balance of power.

The basic reason for this, of course, was the problem of assimilation, which is discussed above. No one of the new weapons was so powerful in its own right that its mere presence on the battlefield would assure victory. Thus, prior to our own time, weapons have influenced international affairs only indirectly and gradually.

The closest thing to an exception seems to have been the threatened antipopulation use of the long-range bomber aircraft in the late 1930s, primarily by Hitler. This threat certainly permitted Hitler to consolidate his control of Central Europe, as was clearly evidenced at Munich, in 1938. But this was only one of a number of factors (though perhaps psychologically the most important at the time). Not only was the decisiveness of

air bombardment by high explosives alone doubted by enough military and political leaders to put the issue to a test within a year, but its significance was soon proven to be somewhat overrated (even though far more effective than many conservative military men had suspected).

But seven years after Munich a new weapon appeared which permitted aircraft bombardment--simply as the delivery system--to accomplish destruction of a magnitude and intensity which had never been dreamed of by Trenchard, Douhet, or Mitchell. This was the atomic bomb, of course.

Nuclear weapons unquestionably have the capability of affecting the balance of power. To date their mere existence has secured a balance of military power between East and West in Central Europe and elsewhere, despite a massive Communist superiority in ground forces.

Until the power of the atomic bomb was demonstrated, no new weapon had been so unmistakably revolutionary that its mere lethality clearly indicated national policy and strategy. And, even in the case of nuclear weapons, tactical and doctrinal response has been difficult and slow. As is clear from the discussion in Annex III-J, the implications of the tactical employment of such weapons are still matters for surmise and conjecture.

Impact of New Concepts on Employment of Existing Weapons

Military tactics, organization, and doctrine are much more likely to be affected by new ideas, new concepts of employing men and weapons, than by the appearance of new weapons alone. More often than not it has been the application of sound, imaginative thinking to existing weapons which has caused the great developments in military affairs, and which has affected international relations. Even the new weapons which were the basis of the revolutionary Macedonian and Roman tactical systems were in reality only modifications of existing weapons.

The importance of new or imaginative ideas in military affairs--as opposed simply to new things--can best be gauged by the fact that it has almost invariably been new ideas which have permitted inferior military forces to overcome forces that were larger and/or better equipped. Hannibal was an outstanding

example of this in antiquity. He had no new weapons (his elephants were relatively ineffective against the Romans), his troops were inferior in quality, training, and weapons. His amazing string of successes was due to his ability to use combined arms, to improvise both strategically and tactically, and in particular to his focus on maneuver. He has rightly been called "the father of strategy," and his imaginative thinking stimulated the development of the modern Schlieffen Plan.

The equally astounding successes of Jenghiz Khan were achieved in almost every instance against forces that were numerically superior and which had similar or comparable weapons. Unlike Hannibal, Jenghiz invariably did enjoy superiority in training and discipline, but this alone could not explain the extent or nature of his conquests. The reason was an incomparable genius for developing new ideas in organization and administration, combined with the same kind of imaginative tactical and strategical genius which Hannibal had displayed. New ideas, unexpected and unknown to his opponents, were the reasons for success.

Equally relevant, although a different kind of example, is the way in which the Swiss used the long pike--almost identical to the Macedonian sarissa--to dominate European battlefields for a century. Combining tactical mobility, speed of movement, surprise, and an unfailing offensive spirit, the unarmored Swiss, in dense columns not unlike the Macedonian phalanx, charged at the run to overwhelm heavily armored knights on horse or on foot, as well as all other varieties of medieval infantry. They were for a while able to maintain an ascendency over early gunpowder weapons, as well, dashing through the beaten zones before enemy fire could do them serious harm, or else attacking by surprise from an unexpected direction before the clumsy existing systems of command and control could respond.

There is, of course, no better example of the impact of ideas on existing weapons than the military system developed by Gustavus Adolphus. As we have seen, he not only modified weapons drastically, he combined them into a military system which, to some extent, has lasted to our own day.

Another example is the adaptation of the flintlock musket to linear tactics by the Prussians. They were not the only ones to do this, but King Frederick William I sponsored the development of an iron ramrod which, when exploited by training, permitted an increase in the rate of fire of the Prussian infantry without in any way changing the weapon or its method of operation.

Prussian training, discipline, and superior firepower--as well as his own imaginative genius--were then exploited by Frederick William's son, Frederick the Great, to make Prussia a great power and to change permanently the balance of power in Europe.

Napoleon introduced neither a new weapon nor a new tactical system. Although he was an excellent tactician, his principal impact on warfare was the injection of new and imaginative ideas into grand tactics and strategy--the most important of these being his concepts of mass and maneuver. One indication of the potential and actual lethality of ideas can be obtained from the comment of one of his enemies (Blucher, although the statement has also been attributed to Wellington), that Napoleon's mere presence in a battle or campaign was worth at least 40,000 men. The strategical concepts of Napoleon, novel at the time, are now commonplace due to the writings of Jomini and Clausewitz.

New ideas of tactics and doctrine can also give the introducing power the advantage of surprise. Twice within the lifetime of men now living the German Army has scored stunning tactical surprises over its opponents, in 1918 and again in 1940, yet in neither case did it use new weapons. Every item in the German arsenal was familiar, yet use of these weapons came as a great surprise.

In the course of history ideas regarding the employment of weapons have been far more important than the weapons themselves, whether these were new weapons, or those that were old and familiar. We were rudely reminded of this by the Chinese Communists in Korea, who had no air support, little armor, relatively weak artillery, and were generally backward in terms of modern weapons and equipment. Yet through a combination of initiative, determination and imaginative exploitation of our previously unrecognized weaknesses, they inflicted some sharp defeats on American forces. In different ways we, as well as the French, have been exposed to similar lessons in Vietnam, where the guerrillas have so deprecated weapons that they have simply used their enemies--us--as an arsenal.

History still shows, as it has time after time, that imagination in weapons employment can make up for clearly discernible qualitative and quantitative inferiority in manpower, or weaponry, or both.

Chapter VI

QUANTIFICATION OF FACTORS RELATED TO WEAPON LETHALITY

In accordance with the study directive requirement to "quantify increases in lethality" where possible, exploratory investigations have been made which have yielded interesting and encouraging results. While time has not permitted extensive study in this area, some valid conclusions can be drawn on the basis of the data considered and results obtained.

Theoretical Lethality Indices

In attempting to quantify lethality it has proved possible to develop reasonable and consistent factors, applicable to any weapon, whose product will give a specific lethality value to such weapon, regardless of type. We have chosen to call these lethality values "theoretical lethality indices."

The factors are: rate of fire, number of potential targets per strike, relative incapacitating effect of each strike, effective range of the weapon, its accuracy, its reliability, its battlefield mobility (where applicable), and its fighting machine capability (for machines such as tanks or combat aircraft). Part One of Annex III-H of this report lists the lethality indices which we have calculated for a number of specific types of weapons, from the earliest hand-to-hand implements to nuclear bombs. Enclosure 1 to that Annex provides a graphical representation of these values, plotted logarithmically over time and revealing clearly the major discontinuities and advances in weapon lethality during the course of history.

In the calculation of these representative theoretical lethality indices, we were struck by the unexpectedly high value derived for the World War II American 105mm howitzer, substantially exceeding the indices of smaller, quicker firing weapons,

as well as those of larger pieces. Accordingly, we have prepared a brief case study of the adoption and assimilation of the 105mm howitzer by the US Army between the World Wars; this, the first specific instance of research and analysis inspired by the development of our lethality indices, appears as Annex III-I to this report.

We believe it may prove significant that we have been able to apply these lethality indices to the problem of relating quantified lethality to tactical factors such as dispersion and mobility--as demonstrated below--in comparative analyses of battlefield experience in four major wars.

Battlefield Effectiveness of Weapons

In order to relate actual battlefield effectiveness of weapons to our lethality indices, it is necessary to undertake detailed investigations of pertinent statistics for a number of modern wars of the 19th and 20th Centuries, and to relate these statistics to each other on the basis of a series of exhaustive calculations. The time pressures affecting this study have prevented us from doing more than establishing a basis for further investigations, calculations, and comparisons. As we had feared, the statistical material for such analysis is sketchy and incomplete, yet we have found that there is sufficient material for the Napoleonic and American Civil Wars to produce some interesting and potentially valuable values for the battlefield lethality of the major weapons of those wars. These values, the basis of their calculation, and a number of other significant and interesting statistical relationships, are discussed and explained in Part Two of Annex III-H, and several of its enclosures.

We feel that the potentialities of this survey of battlefield effectiveness, and the relationship of derived values to the theoretical lethality indices, cannot be fully determined until patterns and trends can be established by similar work (to the extent reliable data is available) for the Mexican War, the Crimean War, the Franco-Austrian War of 1859, the Seven Weeks' War, the Franco-Prussian War, the Russo-Turkish War, the Russo-Japanese War, World War I, World War II, and the Korean War. It will be noted below that we have derived some general figures for the two World Wars, but have not yet had an opportunity to investigate the details of specific battles and engagements as we have done for the Napoleonic and Civil Wars.

Relationship of Lethality, Dispersion, and Mobility

An article in a professional military journal[19] suggested to us an avenue of approach for investigating the relationship between lethality, dispersion, and firepower. Benefiting from our historical survey, from our analyses, and from our development of theoretical lethality indices, we were able to carry this investigation much further, and on a sounder basis, than could previously have been possible.

In essence, on the basis of historical data, we were able to compare "type" (or average) armies or army corps of 100,000 men each for the Napoleonic, Civil, and First and Second World Wars, in terms of (a) the density and shape of deployments; (b) the speed with which reserves could be committed; and (c) total lethality indices for each force, derived by adding the individual lethality indices for each major type of weapon. The results of this comparison are shown in Part Three of Annex III-H.

From our study of history, we know that the major weapons of the time had been fully assimilated in both the Napoleonic Wars and World War II. We also know that new, unassimilated weapons of previously unexpected lethality had frustrated commanders in the Civil and First World Wars and had resulted in heavy casualties as well as tactical and strategic stalemate. Because of this, we are struck by the close consistency in the relationship between dispersion and lethality in the Napoleonic and Second World Wars, and the great differences and inconsistencies in these relationships for the Civil War and World War I. Dispersion is seen to be much less (as it was in historical fact) in proportion to lethality in both of those wars than it was in the Napoleonic Wars and World War II.

Highly significant was the indication that dispersion in World War I, slight though it was in relation to lethality, was at the same time too great for the available means for committing corps reserves. Lethality had obviously far outrun mobility for that war, a situation rectified by World War II. From the combination of inadequate dispersal in terms of lethality, and excessive dispersal in terms of mobility, in World War I we can clearly see: (a) how a stalemate resulted, (b) why it was so

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[19] William G. Stewart, "Interaction of Firepower, Mobility and Dispersion," Military Review, March 1960.

difficult to achieve a tactical breakthrough, and (c) how, once a breakthrough was made, it could not be stopped until it faltered due to its own lack of logistical means.

We wish to stress that these calculations are perforce relatively crude and tentative, and require much further evidence for corroboration. Nevertheless, it does appear that we have developed a basis whereby--at least for wars in the past--we can ascertain the adequacy of dispersal, in terms of lethality and mobility, as follows:

1. A combat force should be so dispersed that it occupies an area (in square miles) at least as large as the value of its composite lethality index (in millions); and

2. A combat force should be so concentrated that its reserves can be committed effectively to any part of its area within a period of approximately four hours.

If the general tactical applicability of lethality indices can be proved for the past, despite great diversities in weapons, there is reason to believe that they will be equally valid for the future.

Chapter VII

LETHALITY AND THE FUTURE

This historical study has reviewed relevant aspects of the relationship between weapons lethality and military doctrine in order to distill from experience wisdom that would be useful to those concerned with tactical and organizational planning for the future. Such a study would be incomplete, however, if it did not indicate how at least some of the trends which have been noted are likely to affect warfare in the future, trends which could be overlooked unless attention is drawn to them directly.

The task of selection and consolidation of the most significant matters for inclusion in this chapter is difficult, since so much of the material in the analytical studies has direct relevance to modern doctrinal and organizational problems. Therefore recipients are urged to look at the annexes because of additional insights which they contain.

Problems of Military Behavior

The survey of national and ethnic reactions to weapon lethality (Annex III-G) has demonstrated that there is insufficient evidence currently available regarding these things upon which to base sound conclusions. Yet the increasing lethality of weaponry makes it extremely important for us to know all that we can about the past military behavior of our friends and prospective foes--as well as of ourselves--if we are to plan adequately for different eventualities in the event of future war.[20]

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[20] Though not directly relevant to our study, there is reason to believe that our national traits hamper us exceedingly in guerrilla war, where weapons are of a lower order of lethality.

We can, of course, draw a number of quite general conclusions on military behavior from the historical experience reviewed in this study. For instance we should recognize that the process of killing in war is not undertaken primarily for the purpose merely of eliminating a dangerous enemy; far more important is the demoralization of those who survive. This has been true over the centuries and remains true even for modern "strategic" air war.

It is evident, also, that large numbers of sick and wounded adversely affect the morale of a military force; convalescents are particularly vulnerable to psychological influences. Obviously there is great moral significance to the unfamiliar, the unknown, and the unseen in war; this has much to do with the general reaction to the possible employment of poison gas in war, as well as to the implications of nuclear radiation.

Yet, we do not understand these things well enough, despite the considerable work that has been done on psychological warfare (mostly in the pressures of conflict in World War I and World War II). It will always be important to maintain the highest possible morale in one's own forces, while attempting to break down the enemy's will. What is needed for this purpose is careful study, based on experience, of the national-cultural aspects of military behavior; of the possible implications of differing ethnic reactions to weapons and weapon effects; of the differences that may exist in the breaking points of different cultures, and the like. In the exploration of these matters military statistics, as well as qualitative historical evaluations, will be important; but the historian will then have to analyze these statistics and evaluations in collaboration with the anthropologist, the psychologist, and the sociologist.

History and Tactical Nuclear War

It is possible to look imaginatively, yet with historical perspective, at some specific aspects of the waging of tactical nuclear war in the future. This is important since there has been a tendency on the part of many--civilian scholars as well as military men--to call upon military history to support various --and sometimes conflicting-- appraisals. The most common, perhaps, is the contention that nuclear weapons, for all of their awesome power, are merely the latest of a series of awe-inspiring weapons which men have been producing for centuries. We are often reminded that a 13th-Century papal edict declared the crossbow to

be an "inhuman" weapon, and banned its use against Christians. Our attention is also drawn to the early 20th Century predictions that the machine gun and high explosives had made war so deadly as to be impossible. Human ingenuity, we are told, has always found a way to control, and to cope with, the deadliest of new weapons.

The historical references are correct. Their relevance to the utilization of nuclear weapons in future warfare is less certain. This relevance depends on the validity of an unstated assumption that there is an established law of nature regarding weapons, which applies to all implements of destruction, no matter what their power may be.

Yet there is nothing in history to assure us that there is an immutable law of nature which applies to weapons. It is not correct to assume--as many do--that there has been a continuum of weapons and weapon effects in history. There have, in fact, been a number of discontinuities, discussed in some detail in this report and its supporting papers. There have been similarities among these discontinuities, but there have been substantial differences as well.

The historian, looking back over the record of past ages, is likely to feel intuitively that man will somehow or other learn to control this new weapon, and to use it in war, as he has done with other weapons in the past. Yet he also notes a discontinuity of unprecedented magnitude. And, if he has any knowledge of military affairs, he cannot avoid seeing unsolved problems in the employment of tactical nuclear weapons, problems which could conceivably remain unsolved so far as traditional patterns of land warfare--or anything like such patterns--are concerned.

Despite continuing efforts by some individuals, the historian cannot prove from history that there are, or are not, solutions to all of the problems of employment of tactical nuclear weapons; he cannot prove that sustained tactical nuclear warfare is either feasible or unfeasible. Nor can he do more than venture a guess as to the outcome if two powers were to initiate tactical nuclear operations, only to discover that continuation of the operations is impossible, due to inability of the conflicting forces to fight and survive in a nuclear environment.[21] A

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[21] This term requires further investigation and definition. For our purposes, it is assumed to be a physical and military environment which would be created by consistent and systematic

knowledge of nuclear weapons provides a basis for analysis which can merely suggest that tactical nuclear warfare will be difficult in the extreme and, if feasible, will be far different from any kind of warfare man has ever known.

This would not justify a conclusion that tactical nuclear warfare is impossible, or that it will be avoided by the powers because its problems seem unsolvable, or that initiation of a tactical nuclear war will inevitably result in escalation to general nuclear war. Any one of such conclusions might prove right at some indefinable future time, but this we can never know until or unless the time comes; the authors of this report are neither seers nor prophets.

There is evidence upon which to base a conclusion, however, that a number of things will have to be done before sustained tactical nuclear operations are likely to be feasible. It is even possible that, despite the most intensive possible efforts, such feasibility cannot be achieved. Nevertheless, regardless of difficulties and implications, these things must be attempted lest, in the words of Clausewitz, "some one steps in with a sword that is sharp and lops off the arm of our body."

For the foreseeable future a nuclear capability alone, without a conventional capability as well, is likely to be disastrous. And in order to assure compatibility between these capabilities, there is need for radically new approaches in the design of weaponry and equipment. This is particularly true in the logistical field, where some vulnerabilities now appear almost insurmountable.

This study has, we believe, provided a basis for undertaking serious and profitable analysis of one of the problems of tactical nuclear warfare: the relationship of weapon lethality to dispersion and in turn to the deployment and commitment of reserves. One test of the viability of current organizations and operational concepts, or of those under study by AVTAC or other agencies, could be the application of the considerations discussed in Chapter VI of this report, and in Part Three of Annex III-H. It might be ascertained in some instances, for instance, that the indicated dispersal of forces would have to be so great that they would be relatively ineffective. While this would not necessarily be a conclusive test, its results should be very useful for purposes of planning and evaluation.

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use of tactical nuclear weapons as the principal determinants of the outcome of a major ground engagement.

This study has also revealed the need for urgent examination of three essential human considerations, which may take precedence over many important doctrinal and material requirements. First of these is morale. The problems of maintaining morale in a tactical nuclear environment will be staggering, and without morale there cannot be effective combat capability. Second, and contributing also to the first, is survivability. Neither men nor their equipment can be considered expendable in modern society as once they were, and proper protection for both in a nuclear environment will be very difficult. Third is leadership. No less than formerly, trained leadership is essential in battle. In any future war the problems of command and control will be greater than in the past, need for initiative will be more pronounced, and yet inhibitions on independent decisions will be more restrictive; battlefield emergencies in nuclear war will not be solvable by technical devices or routine operating procedures.

We urge that these three matters receive early, objective, and thorough consideration.

Chapter VIII

CONCLUSIONS AND RECOMMENDATIONS

Conclusions

1. Prior to the development of nuclear weapons, there were three major advances in weapon lethality which created significant discontinuities in military tactics and organization: (a) the adoption of gunpowder weapons; (b) the introduction of the rifled musket with a cylindro-conoidal bullet; and (c) the combined impact of automatic weapons and high explosives on the battlefield.

2. The individual soldier has become increasingly independent in combat; this in turn has not only called for improved training, discipline, motivation, and coordination, it has also required fostering improvement in intelligence, initiative, and judgment on the part of each individual at lower levels.

3. The process of doctrinal assimilation of new weapons into compatible tactical and organizational systems has proven much more significant than invention of a weapon, or adoption of a prototype, regardless of the dimensions of the advance in lethality.

4. Assimilation of a significant increase in lethality has generally been marked by dispersion, thus reducing the number of people exposed to the new weapon in the enemy's hand; by giving greater freedom of maneuver; and by improving the cooperation between the different arms and services.

5. The pace of military invention, in development of new and improved weapons, has generally followed that of the accelerating pace of the Industrial Revolution, with the result that the interval from conception of a new or radically modified weapon, to the time of adoption of a workable prototype has generally been growing shorter.

6. In modern times new and radically improved weapons have been appearing in groups some 15 to 20 years following major wars; this time lag is partly due to budgetary and stockpile considerations; it is also due in large measure to the satisfaction of wartime leaders with the weapons and methods which they became familiar with in combat, with consequent lack of interest in new developments until a new generation of leaders appear.[22]

7. In modern times--and to some extent in earlier eras--there has been an interval of approximately 20 years between introduction and assimilation of new weapons into compatible military systems; this time lag is in part due to the leadership problem noted above; it is significant that, despite the rising tempo of invention, this time lag has remained relatively constant, including current efforts to assimilate tactical nuclear weapons into US Army doctrine.

8. The criteria for the assimilation of new or greatly modified weapons are:

a. Confident employment in accordance with a doctrine assuring compatible coordination with other weapons;

b. Consistently effective, flexible use in offensive warfare, permitting full employment of advantages of superior leadership and/or resources;

c. Doctrinal capability for dealing effectively with anticipated and unanticipated countermeasures; and

d. Decline in casualties for the employers of the weapon, often combined with a capability for inflicting disproportionately heavy losses on an emeny.

9. The pre-conditions for assimilation have been:

a. Imaginative, competent, knowledgeable leadership;

b. Effective coordination of a nation's economic, technological-scientific, and military resources;

c. Opportunity for evaluation and analysis of battlefield experience.

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[22] For significant exception to this general rule, see Annex III-I.

10. For the mid-20th Century no way has yet been found to assure the first of the above-pre-conditions, or to permit the last in peacetime; the second of these, however, can be assured if the following institutional arrangements and policies exist:

a. Industrial or developmental research institutions, basic research institutions, general and technical military staffs and their supporting agencies, together with administrative arrangements for linking these with one another and with the top decision-making echelons of government.

b. Conduct of research, developmental and testing activities by these bodies through mutually familiar methods and procedures so that their personnel can communicate, can be mutually supporting, and can evaluate each other's results; and

c. Direction of the efforts of these institutions--in all matters relating to weaponry and doctrine--toward a common and clearly defined goal.

11. There are indications that the development of imaginative, competent, knowledgeable military leadership can be assured, or at least enhanced, by an intensive effort to analyze the causes and essential nature of military creativity, and to develop presumably achievable means for stimulating and enhancing such creativity and for elimination or suppression of the inhibitions to such creativity.

12. Consistent leadership in producing effective military innovations in the modern world is not accident nor the reflection of some racial military aptitude but is a function of administration which shares the rational and scientific outlook in common with supporting research and industrial institutions.

13. Prussian-German pre-eminence in military affairs for the century from 1841 to 1941 was due in large part to realization by Prussia and Germany, before other nations, that the Industrial Revolution required a systematic approach to assimilation of weapons and doctrine along the lines suggested by conclusions 9 and 10 above; this organization, built around their Army's General Staff, also permitted them to exploit fully and promptly their own battlefield experience and that of others; the results gave Germany significant, and in some instances decisive, military advantages over other nations, or numerically superior combinations of nations which had comparable or superior scientific and technical capabilities.

14. There is an indication that a technological breakthrough can be expected in the near future which may permit--in peacetime--true battlefield testing essential for assimilation.

15. Pending achievement of this breakthrough, the accelerating tempo of technology is placing pressures on the military to make sweeping changes in weaponry and tactics without the battlefield testing which in the past has been essential for assimilation.

16. Save for the recent, significant exception of strategic nuclear weapons, there have been no historical instances in which new and more lethal weapons have, of themselves, altered the conduct of war or the balance of power until they have been incorporated into a new tactical system exploiting their lethality and permitting their coordination with other weapons; the full significance of this one exception is not yet clear, since the changes it has caused in warfare and the influence it has exerted on international relations have yet to be tested in war.

17. Until the present time, the application of sound, imaginative thinking to the problems of warfare (on either an individual or institutional basis) have been more significant than any new weapon; such thinking is necessary to real assimilation of weaponry; it can also alter the course of human affairs without new weapons.

18. Theoretical, quantified, lethality indices, applicable to all weapons, can be derived by applying to the characteristics of a weapon the factors of rate of fire, number of targets per strike, relative incapacitating effect per strike, effective range, accuracy, reliability, battlefield mobility (where applicable), and fighting machine capability (where applicable).

19. Theoretical lethality indices appear to provide a basis for (a) selecting significant weapons developments in history for special analysis and (b) relating weapon lethality to tactical dispersion and mobility for analytical purposes.

20. There is a serious and major requirement for intensive collection, collation, and analysis of military statistics, to put to use the great mass of experimental data which has been generally neglected.

21. Relationships between lethality, dispersion, and the mobility of reserves, as developed in this study, may prove useful in testing the possible battlefield viability of current or proposed organization and doctrine of tactical nuclear combat forces.

22. The assimilation of tactical nuclear weapons into a viable military doctrine poses unprecedented difficulties; but three major human issues require the most urgent attention: morale, survivability, and leadership in the environment of a nuclear battlefield.

23. There is need for further investigation of psychological influences in wars of the past to provide insights relevant to likely military behavior of different national and ethnic groups in warfare of the future.

24. There is need for carefully developed educational programs to foster the understanding and transfer of ideas between the mid-range personnel of the many specialized institutions and professions now concerned with preparation for war.

Recommendations

1. There should be a comprehensive review of present US Army methods, procedures, and organizations related to the development of tactics, organization, and doctrine for assimilation of new and prospective weapons; this review should focus on budgets, institutional arrangements, utilization of existing means, and the development of new means to assure the most adequate possible testing and evaluation in peace and in war.

2. Means of fostering military creativity should be explored.

3. The learning process in the armed forces should be critically examined, subjected to systems analysis, and arranged to ensure that it will continually acquire, process, store, retrieve, analyze, and publish data and conclusions relevant to combat effectiveness, and that this data will then be presented in timely fashion to the appropriate staffs and commanders, at all levels.

4. Basic research in the related processes of the invention of weapons, their adoption, and their assimilation through changes in tactics, organization, and doctrine, is badly needed. Authoritative studies of the actual functioning of the German General Staff, for example, are not to be found, yet it was a key factor in the development of modern military practices. Case histories in scholarly monograph form of significant tactical innovations and increases in lethality of weapons would provide

material for analysis in depth and later recommendations in regard to US policies and institutions.

5. The US Army should encourage research into the history, economics, and sociology of military staffs and institutions as it now encourages research in the natural sciences.

6. A research program should be undertaken leading to improved utilization of quantified or quantifiable military experience and statistics, and to include exploration of new vistas in quantification revealed in this study.

7. Studies should be made of the major human factors in future war, with particular emphasis on the problems of morale, survivability, and leadership in the environment of the tactical nuclear battlefield.

8. Intensive interdisciplinary investigation should be undertaken of the cultural aspects of military behavior, and particularly the military effect of psychological influences on different national and ethnic groups.

9. Educational programs should be prepared--if possible on an interservice national basis--to foster closer understanding and better transfer of ideas between mid-range personnel of the many specialized institutions and professions--military and civilian--now concerned with preparation for war.

Appendix A

EXTRACT FROM STUDY DIRECTIVE FOR STUDY

"An Historical Analysis of Trends in Military Organization and Tactics as Weapon Lethality Has Increased"

General

A study to identify and analyze critical relationships and the cause-effect aspects of major advances in the lethality of weapons and associated changes in tactics and organization.

Objective and Scope

To derive from study and analysis of history the characteristics of the interplay among major elements of military power. Study should cover the period from Roman times to the present and should focus on cause, effect, and character of great advances in weapon lethality. Analysis should identify the origins of major increases in lethality; the time lag between discovery of means and development of effective methods of employment; the impact, where possible, on the existing balance of power; and the quantification of increases in lethality, where feasible.

Guidance

a. Study should be concise and oriented toward the specific areas of inquiry indicated in the scope. Descriptive narrative should be detailed enough to establish clearly the basis for analysis but should be limited to an account of events, activities, and results directly pertinent to the relationships under examination.

b. Changes such as the lengthening (or shortening) of swords, variations in propelled weapons, the use of gunpowder and fire weapons, major improvements in hand weapons (rifling, breech-loading, etc.), increases in rates of fire (the machine gun), and in terminal lethality (HE) plus chemical weapons should be included.

c. The identity of the origin of major advances in lethality (nation, organization, individual) and the time lapse between discovery or development of the means and the application (know-how) of the means of weaponry should be established.

d. For each major advance in lethality of weapons, the time lag between the invention of the means and the development of effective methods for applying those means for military purposes should be determined.

e. Instances where the recognized need for changed methods of operation gave rise to development of increased lethality should be cited and analyzed. Of related interest are the cases in which improved or radically new methods of employing weapons which were generally known and available were responsible for major victories or defeats.

f. Study should include information as to how and by whom new concepts of employment were developed. Were they developed by the military or by others? Were they developed in school environments, in staff organizations, or in the field? Were they developed prior to the onset of war or during the war?

g. Quantification of study results is desired. This might be expressed in terms of increased casualty rates or in the increased range at which battles were fought or in terms of increased dispersion of forward forces which was forced by the increased lethality of weapons.

Appendix B

HISTORICAL TRENDS RELATED TO WEAPON LETHALITY

Basic Historical and Analytic Studies

CONTRIBUTIONS AND CONTRIBUTORS

AGE OF MUSCLE

Name	Title	Page-length
Rothenberg	Individual weapons of the Age of Muscle	25
Starr	The sword and other weapons of the Age of Muscle	12
Rothenberg	Group weapons of the Age of Muscle	9
Hayes	The Macedonian phalanx	5
Starr	The Roman legion	10
Onacewicz	Armored cavalry systems	26
Hayes	Mongol cavalry system	8
Paret	Swiss phalangial column system	10
Hayes and T.N. Dupuy	Rise of Infantry, the crossbow	8
Hayes and T.N. Dupuy	The English longbow tactical system	8

AGE OF GUNPOWDER

Name	Title	Page-length
Rothenberg	Individual weapons of the Age of Gunpowder	53
Rothenberg	Group weapons of the Age of Gunpowder	51

Leighton	Introduction of gunpowder	88
Morton	Development of tactics in the 17th and 18th Centuries	97
Rothenberg	Light infantry concept	25
Paret	Columnar tactical systems	7
Sunderland	Massed mobile artillery	3

AGE OF TECHNOLOGICAL INNOVATION

Name	Title	Page-length
Johnson	Development of small arms and automatic weapons, 1850-1960	506
Mesick	The rocket launcher	3
Mesick	Tube artillery	28
T.N. Dupuy	Development of combat aircraft to support ground combat	12
Mesick	The tank	10
Sunderland	The flame thrower	3
Mesick	Rocket-type missiles	10
Reinhardt	Nuclear weapons	10
Sunderland	Land mines	2
Reinhardt	Antipersonnel mines	15
Reinhardt	Non-explosive weapons	9
Onacewicz	19th Century combined arms divisional systems, 1796-1845; 1879-1900	36
Andrews	19th Century combined arms divisional systems, 1845-1878	21
Andrews	German innovation of combat team in WWI	10
Andrews	The German armored division of 1940	21
Andrews	The German airborne task force	13
Marshall	Origins of modern fire power	8
Marshall	Allied amphibious operation in WWII	31
Ropp and Shaw	Interservice joint operation task forces	48
Ropp	Innovations in land warfare	12
Shaw	Development of amphibious warfare, combat teams, and task force organizations	17

TECHNOLOGY AND WEAPONS DEVELOPMENT IN HISTORY

Name	Title	Page-length
Mesick	Metallurgy and metal working	8
Leighton	Metallurgy, chemistry, ballistics	68
Gilfillan	Electronics	38
Reinhardt	Nuclear science	6
Eacum	Logistics	36

COMPARATIVE ANALYSIS OF HISTORICAL STUDIES

Name	Title	Page-length
Ropp	Analysis of effects of changes in weapon lethality	18
Ropp	The process of military creativity	9
Possony	Lethality in tactical nuclear warfare	16
Possony	Lethality in strategic nuclear warfare	12
Possony	Morale, national psychology and weapon lethality	10
Gilfillan	Development of numerical planning factors	5
Reinhardt	Observations on quantification	6
T.N. Dupuy	Quantification of factors related to weapon lethality	52
Sunderland and T.N. Dupuy	Impact of imaginative thinking on military organization and tactics	10
Shaw	Effects of changes in organization and tactics on effectiveness of existing weapons	7
Onacewicz	Effects of tactics on development of weapons	15
Gilfillan	Organization for development of new or improved weapons	6
R.E. Dupuy	Development of the 105mm howitzer	8
Possony	Weapon lethality--general considerations	33
T.N. Dupuy	Distorted historical perspectives of tactical nuclear warfare	20

MAJOR ADVANCES IN WEAPONS LETHALITY (See notes on next page)	New or modified weapon?	Imposed by superior tact. prob?	Date of invention	Date of adoption	Date of Assimilation	Time lag (yrs) from adoption to assimilation	7. Circumstances of Adoption: a Key personnel in invention and/or adoption	b National-ity	d Earl... 1) Cau-lity eff.
1 [illegible] (Pike)	[illegible]	yes	?	[illegible]	[illegible]	20	Philip	[illegible]	
2 [illegible] (Sword)	mod	yes*	?	250 BC	200 BC	30-50	?	Rom.	?
3 English [illegible]	[illegible]	yes	?	1260	1346	66	Edward I	Eng.	W
4 [illegible] Bow	[illegible]	no	?	?	[illegible]	?	?	?	W
5 [illegible] Cannon (a)	new	no	1320	1370	[illegible] 1400	100+ 170	[illegible] Bureau Bros.	Ger. Fr.	W
6 [illegible] (Culverin) (b)	new	no	1411	1450	1540	90	?	Sp.	W
7 [illegible] (Sakre) (b)									
a: Matchlock musk.	mod	no	1510	1540	1620	80	See § above	Sp.	W
b: [illegible] Pistol	mod	no	1540	1700	1870	130	See § above	Fr.	
8 [illegible] Bayonet (d)	mod	no	1613	1690	1760	90			
9 [illegible] Conical Bullet (e)	mod	no	1500	1830	1885	15-55	[illegible] Minie		
10 [illegible] Rifling (f)	mod	no	1?	[illegible]	1870	22-50	[illegible]		
11 [illegible] Rifled Cannon (g)	mod	no	1?	[illegible]	1871	21	[illegible]		
12 Machine gun (h)	new	no	1862	1890	1917	27	[illegible]	[illegible]	
13 High Explosive Shell (i)	mod	no	1800	1880	1915	25	[illegible]	[illegible]	
14 [illegible] Magazine Rifle (j)	mod	no	1867	1890	1914	24	Hiram Mc Cl	Am.	
15 Tank	new	yes	1915	[illegible]	1939	24	[illegible]	Br	
16 Combat Aircraft (Fighter Bomber)	new	no	1903	1917	1939	22	[illegible]	Br	
17 Ballistic Missile (k)	new	no	1925	1945	?	?	[illegible]	Am	W
18 Atomic Bomb	new	no	1945	1945	?	?	Einstein Fermi, etc.	Ger It	W

Appendix C--ADOPTION AND ASSIMILATION OF MAJOR ADVANCES IN WEAPON LETHALITY

5 Date of Assimilation	6. Time lag (yrs) from adoption to assimilation	7 Circumstances of Adoption			d Early effects			8 Circumstances of Assimilation					9 Complete or relative assimilation	10 Primary basis of new tactical syst.	11 Relative significance of weapon & syst.
		a Key personnel involved in inventing and/or adoption	b Nationality	c Peace/War	(1) Casualty eff.	(2) Combat effectiveness	(3) Combatability w/ weapon	a Key Personnel or Event Involved	b Nationality	c Peace/War	d Effects (1) Casualty effects	d Effects (2) Combat effectiveness			
c339BC	20	Philip	Macedon	?	Good	Good	Fair	PhilipALEXANDER	Macedon	W	Exc	Exc	Comp	Yes Phalanx	Syst
c200 BC	30-50	?	Rom.	?	Fair	Poor	Poor	?	Rom.	W	Exc	Exc	Comp	Yes Legion	Syst
1346	66	Edward I	Eng.	W	Good	Good	Fair	Edward III	Eng.	W	Exc	Exc	Comp	Yes EngBattle	Syst
c1220	?	?	?	?	Good	Good	Fair	Jenghis Khan	Mon.	?	Exc	Exc	Comp	partly	Syst
c1420-1490	100-170	Zizka Bureau Bros.	Ger. Fr.	W	Poor	Poor	Poor	Charles VII	Fr.	?	Fair	Fair	Rel	No	NA
c1540	90	?	Sp.	?	Poor	Poor	Poor	Gonsalvo de Cordova et al	Sp.	W	Fair	Fair	Rel	Yes, Span Square	Weap
c1620	80	See 6 above	Sp.	W	Fair	Fair	Fair	Gustavus	Swed	W	Good	Good	Rel	Yes,linear	Syst
c1670	180	See 5 above	Fr.	?	Fair	Poor	Poor	Gustavus	Swed	W	Good	Good	Comp	Yes,linear	Syst
c1700	50	Lesourgeoys(musk) Vauban(bayonet)	Fr. Fr.	P	Fair	Fair	Good	Wars of Louis XIV	Fr.	W	Good	Good	Comp	No	Both
c1865	15-35	Norton Dalvigne,Minie Wolowski	Brit Fr	P	Good	Fair	Fair	Am. Civil War	Am.	W	Exc	Good	Rel	No	Weap
1870	22-50	Fred [illegible] IV,Hall Von Dreyse	Prus Pr	P	Good	Good	Fair	Von Moltke	Ger.	W	Exc	Exc	Rel	No	Weap
c1871	21	Cavalli Fahrendorff Armstrong,Whitworth	Sard Swed Brit	P	Good	Good	Fair	Franco-Prus. War 1870		W	Exc	Exc	Rel	No	Weap
1917	27	Hotchkiss Browning,Lewis	Am Am	P	Exc	Good	Fair	WW I		W	Exc	Exc	Comp	Yes(20th Cent (?))	Both
1915	25	Nobel	Swed	P	Exc	Good	Good	WW I		W	Exc	Exc	Comp	Yes(20th Cent (?))	Both
1914	24	Mauser et al	Ger	P	Good	Good	Good	WW I	Ger	W	Exc	Exc	Comp	No	Weap
1939	23	Sidon/Churchill	Br	W	Good	Fair	Fair	Ger Gen Staff	Ger	W	Exc	Exc	Comp	Yes(20th Cent ??)	Both
1939	22	Trenchard	Br	W	Good	Fair	Fair	Ger Gen Staff	Ger	W	Exc	Exc	Comp	Yes(20th Cent ??)	Both
?	?	Goddard	Am	W	Good	Fair	Fair	It is not yet certain if it has been assimilated							
?	?	Einstein Fermi, etc.	Ger It	W	Exc	Exc	Fair	It has not yet been assimilated							

Notes to Appendix C

a. Relates to field artillery, not siegecraft

b. Arquebus was a development from early handgun

c. Note later refinements by Frederick and Gribeauval

d. Bayonet permitted complete assimilation of gunpowder weapons

e. Impetus to dispersal

f. Impetus to dispersal

g. Impetus to dispersal

h. Required dispersal

i. Required dispersal

j. Mauser, also Mannlicher, Lee, Springfield

k. Non-nuclear warhead

Appendix D

ANCILLARY TECHNOLOGICAL DEVELOPMENTS AFFECTING WEAPONS LETHALITY

Age of Muscle

1. Armor. Prehistoric men protected themselves from the blows of their opponents with crude shields of hide and then of wood. Rudimentary armor was worn by soldiers in Egyptian and Mesopotamian armies, reaching a new sophistication in Hellenistic Greece with the development of the metallic helmet, cuirass, and shield. An important development in body armor was the introduction of mail early in the Christian era. Mail continued to be the main defense of the body and limbs through the 12th and 13th Centuries until the 14th Century when plate armor began to displace mail. Armor, of course, was intended to inhibit the lethality of a foe's weapons, while its protection provided moral encouragement for more aggressive--and hopefully more lethal--employment of one's own weapons.

2. Stirrup. Although possibly used in parts of Asia as early as the 1st Century A.D., the stirrup came into general use in Europe during the 6th or 7th Century. This device significantly increased (a) the lethality of the lance by putting the total weight of horse and rider behind its impact and (b) the lethality of the bow and the sword, by giving the horseman a secure mounting from which to use these weapons.

The result of both the above developments was a system of armored cavalry which became the dominant arm in Europe for the next 800 years until the successive impacts of the longbow and the Swiss pike were felt.

Age of Gunpowder

3. Stable gunpowder (Corned powder). About 1450, someone found a way of preparing gunpowder so that it retained its explosive qualities and did not separate into its basic ingredients. This made it reliable and so greatly enhanced its effectiveness.

4. Matchlock mechanism. In the 15th Century, the Spanish developed a system of ignition of the arquebus which made ignition a more secure and safe process and which permitted the user to aim while firing, thus considerably increasing both the accuracy and the lethality of the weapon.

5. Flintlock mechanism. This was a safer, surer and speedier method of ignition of the musket which superseded the matchlock mechanism. It involved basically the use of mechanical devices in which pyrite or flint was struck against steel to produce sparks igniting the priming powder in the pan. This development increased the effectiveness of the musket by concealing its ignition during night operations, preventing hazards to the individual, permitting operations in rain, and lessening delay in firing when attacked by surprise.

6. Iron ramrod. In the early part of the 18th Century, Frederick William I of Prussia introduced an iron ramrod to replace the former fragile wooden ramrod. The new implement, when exploited by training (the weapon itself being unchanged) permitted an increase in the average rate of fire of the Prussian infantry (from twice to at least three times a minute).

Age of Technological Change*

7. Steam engine (1769). The patenting of the steam engine by Englishman James Watt, and the subsequent development of the railroad and the locomotive, made it possible to move large masses of men and for them to use weapons [illegible]

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*Not mentioned below, but also contributing to our all military capabilities were such advances as mass-production techniques for weapons and supplies, food preservation, advances in medicine and engineering.

rates of fire by bringing forward ammunition in the quantities these weapons could use. Steam power also permitted mass production of weapons for mass armies.

8. Percussion cap (c. 1815). In the early 19th Century, the percussion cap, introduced by an American, Benjamin Shaw, superseded the flintlock mechanism. In addition to its application to the military musket, it made possible the invention in 1835 of the Colt revolver.

9. Electronic Communication. In the mid-19th Century electricity first made possible long-distance, instantaneous communication, permitting the command and control of large masses of men in combat.

a. The telegraph (c. 1840) was the first important manifestation of this development. Telegraph was used extensively in the Civil War for strategic and tactical direction of large forces.

b. More recently, instantaneous voice transmission was achieved first by field telephone, first used on a large scale in World War I, primarily for artillery communications, in transmission of firing data and corrections from artillery observers to the guns.

c. Voice Radio also appeared in primitive form in World War I, but became the primary means of strategic and tactical control in World War II. It supplemented the telephone and replaced it entirely in operations of highly mobile units over great distances.

10. Barbed Wire. Originally a harmless farming device, barbed wire more fully exploits the lethality of automatic weapons by holding their targets in the line of fire and by keeping them away from the gun and its crew. It was first adapted to these military purposes in 1874.

11. Smokeless powder (1885). Because it permitted users of the weapons to continue to see their targets while maintaining a steady rate of fire, its introduction marked a significant increase in the lethality of the weapons, which also became less vulnerable to countermeasures since their concealment was not betrayed by smoke.

12. The internal combustion engine. Appearing in workable form in 1887, this soon afterward made possible both the tank and aircraft, and permitted dramatic new concepts of warfare. By propelling trucks and track-laying vehicles it has given both road and cross-country mobility to infantry, artillery, and supply trains.

13. Recoil mechanism, quick-firing artillery (1890-1910). The full capabilities of breech-loading cannon could not be exploited until means had been found for the carriage to absorb the recoil, so that the cannon did not have to be man-handled back into place and re-laid for direction and range after each round. When this was accomplished by sophisticated recoil mechanisms, this period produced a whole family of cannon marked by long range, greater accuracy, and (particularly) greatly increased rates of fire. Other improvements in heavy ordnance construction methods, such as built-up tubes, also contributed to this advance in artillery lethality. By 1914 this significant increase in lethality, among others, contributed to rendering linear tactics obsolete.

14. Observation aircraft. First developed in 1907, but not fully exploited until World War I, these helped reveal targets (mainly for artillery) that would have been hidden in past years.

15. Photography. In conjunction with the observation aircraft, the camera, another development of the technological age, has become an essential means of target acquisition, primarily, although not solely, through air photographs.

16. Radar. In essence, this electronic device sends out impulses, which are reflected back from objects in the air, or projecting above the surface of the earth.

a. Defensive use (1938). Radar has given observers a completely new capability in acquiring and identifying targets in the air, on the ground, and on the surface of the sea; this in turn more fully exploits the lethality of weapons for which they are observing. Its capabilities were first understood and employed by the British in their air defense system, and it was a major factor in their decisive victory in the Battle of Britain (1940).

b. Offensive use (1944). The VT-fuze, or proximity fuze, took advantage of the radar principle to permit the detonation of a high-explosive shell when it came near a

target. Previously, a time-mechanism fuze was used to detonate shells in the air. This process was expensive, and was the result of complex and relatively unreliable calculations. Consequently time fuzes were only marginally effective in battle. The inclusion of a tiny radar set in a fuze, however, caused the fuze to detonate the shell when it came within a prescribed distance of the earth, or of an object projecting above the earth, or of any clearly defined object in the air, such as an airplane. Thus for the first time, the maximum lethal potentialities of high explosive could be achieved against any target if the shell were aimed to pass close enough to it.

17. Inertial and Electronic guidance. These are methods of guidance or navigation to provide accuracy in direction and range for long-range ballistic missiles.

Appendix E--DEVELOPMENT OF MAJOR ANCILLARY TECHNICAL DEVELOPME

Ancillary Technical Developments Affecting Weapons Lethality	1. New or modifi. of early dev.	2. Inv. or dev. to meet problem	3. Date of Invention	4. Date of Adoption	5. Key Personnel Involved	6. Nationality	7. Major contributions to new tacti-
1. Armor	new	no			?	?	No
2. Stirrup	new	no	c.200?	c.500	?	?	Yes, me
3. Corned powder	mod.	no	c.1420-1429	c.1420	?	?	No
4. Matchlock Mechanism	mod.	no	c.1476	c.1520	?	?	Yes, Sp
5. Flintlock Mechanism	mod.	no	c.1615	c.1650	Le Bourgeoys	Fr	No, but
6. Iron Ramrod	mod.	yes	1719	1719	Fred. William I	Pr	No
7. Percussion Cap	new	no	c.1807-1816	1820	Forsyth, Shaw	Scot, Am	Yes, In
8. Smokeless Powder	mod.	yes	1884	1885	Vielle, Nobel	Fr, Swed	No
9. Recoil Systems	mod.	no	1888	c.1897	Haussner	Ger	No
10. Internal Combustion Engine	new	no	1680-1886	c.1887	Huygens Otto	Dutch Ger	Armored
11. Electronic Comcatns.							
a. Telegraph	mod.	no	1832	1851	Morse	Am	No, pri
b. Telephone (field)	mod.	no	1876	1876	Bell	Am	Yes, fi
c. Voice Radio	mod.	no	1896		Marconi	It	Yes, fi
12. Radar							
a. Detection & Identification	new	no	1922	1936	Taylor Young Wattson-Watt	Am Am Brit	Yes, fi etc.
b. Proximity Detonation (VT Fuze)	mod.	yes	194-	1944	?	Am	Yes, fi craft a
13. Inertial & Elec.Guid.	new		1914	1933	E. A. Sperry	Am	
14. Photography(Aerial)	new	no	1839	c.1905	Daguerre	Fr	No
15. Barbed Wire	mod.	yes	1874	1915	Glidden	Am	No
16. Observation Aircraft	mod.	no	1903	1907	Wright Bros.	Am	No

dix E--DEVELOPMENT OF MAJOR ANCILLARY TECHNICAL DEVELOPMENTS AFFECTING WEAPONS LETHALITY

Problem	3. Date of Invention	4. Date of Adoption	5. Key Personnel Involved	6. Nationality	7. Major contributions to new tactical system	8. Remarks
			?	?	No	
	c.200?	c.500	?	?	Yes, med. cav.	Stirrup is item of sigif. Date of invent. obs.
	c.1420-1429	c.1420	?	?	No	Made explosion uniform
	c.1476	c.1520	?	?	Yes, Span. Square	
	c.1615	c.1650	Le Bourgeoys	Fr	No,but req. linear tact.	Permitted more reliable ignition
	1719	1719	Fred. William I	Pr	No	Increased speed of fire
	c.1807-1816	1820	Forsyth, Shaw	Scot, Am	Yes, Inf. tactics	Sharply reduced misfires
	1884	1885	Vielle, Nobel	Fr, Swed	No	
	1888	c.1897	Haussner	Ger	No	Improved rate of fire & accuracy;built up tubes contr. to gr.adv. in heavy ordn.
	1680-1886	c.1887	Huygens Otto	Dutch Ger	Armored & air combat	Made tank, aircraft possible
	1832	1851	Morse	Am	No, primarily strategic	These communications advances were critical contributions to command & control of weapons of greater range & weapon systems of accelerating mobility.
	1876	1876	Bell	Am	Yes, field artillery	
	1896		Marconi	It	Yes, field artillery	
	1922	1936	Taylor Young Wattson-Watt	Am Am Brit	Yes, fighter defense, etc.	
	194-	1944	?	Am	Yes, field & antiaircraft artillery	Improved fire effect
	1914	1933	E. A. Sperry	Am	?	Improved command-control
	1839	c.1905	Daguerre	Fr	No	Facilitated reconnaisance; military intelligence
	1874	1915	Glidden	Am	No	Made machine guns & artillery more effective
	1903	1907	Wright Bros.	Am	No	Made artillery more effective; facilitated reconnaisance

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Appendix F--MAJOR LAND-BASED MILITARY SYSTEMS AND SUBSYSTEMS

MAJOR LAND-BASED MILITARY SYSTEMS AND SUB-SYSTEMS	1. Date of appearance	2. Period of dominance	3. Name of originator, or circumstances of origination	4. Nationality	5. Name of Perfector	6. Nationality
1. Macedonian Phalanx	c.359BC	350-197 BC	Philip II	Mace	Alexander	Mace
2. Roman Legion	3dCy BC	197-378 AD	?	Rom	Scipio	Rom
3. Byzantine Turma	580	c600-1072	Maurice	Byz	Leo Belisarius	Byz
4. Med. Eur. Battle	c.500	750-1346	?		Charlemagne	Fr-Ger
5. Mongol Toumai	c.1206	13th Cty	Janghiz Khan	Mong	Jang Khan, Sabutai, Kublai, etal	Mong
6. Eng. Longbow Battle	c.1280	14thCty	Edward I	Eng	Edward III	Eng
7. Swiss Phalangial Column	14thCty.	15-16Cty	Foot Soldiers	Swiss	Various	Swiss
8. "Spanish Square"	c.1540	17thCty	Gonsalvo de Cordova	Sp	Various	Sp
9. Gustaan Linear Formtn.	c.1630	17thCty	Gustavus	Swed	Frederick the Great	Pr
10. Massed Mobile Art. (Sub-syst)	c.1630		Gustavus	Swed	Frederick the Great Gribeauval	Pr Fr
11. Light Infantry (Sub-system)	c.1740		Silesian War	Aust	Moore, Morgan	Br-Am
12. 19th Cent. Division	1759	c1800-1914	Duc de Broglie	Fr	Napoleon	Fr
13. 20th Cent Combat Team	1917	1918-?	Hutier, et al	Ger	Ludendorff & Gen. Staff	Ger
14. Intsvice Joint Ops Tsk Frce	1942	1942-?	US-Br Servs in WWII	US-BR		
15. Lg-Range Air Bombrdmt	1915	1941-c1960	Mitchell, Trenchard Douhet, Zeppelin	Am-Br Fr-Ger	Harris, Arnold	Am, Am
16. Am. Art. Fire Support Syst. (Sub-system)	1918-1938		Summerall, et al	Am	Field Art. School	Am
17. Anglo-Am. Tact. Air Support Syst. (Sub-syst.)	1940		Luftwaffe	Ger	Tedder Montgomery	Br Br

-MAJOR LAND-BASED MILITARY SYSTEMS AND SUBSYSTEMS OF HISTORY

	3. Name of originator, or circumstances of origination	4. Nationality	5. Name of Perfector	6. Nationality	7. Name of reorganizer	8. Nationality	9. Major Weapon	10. Subsidiary Weapons	11. Cause of decline or collapse
	Philip II	Mace	Alexander	Mace			Sarissa	Bow Javelin	Defeated by Legion at Cynoscephalae
	?	Rom	Scipio	Rom	Marius	Rom	Gladius	Pilum	Def. by Gothic cav. at Adrianople
072	Maurice	Byz	Leo Belisarius	Byz	Nicephorus Phocas et al	Byz	Bow, lance Javelin	Broad-sword, dagger,axe	Def. by Turkish cav.at Manzikert
46	?		Charlemagne	Fr-Ger	Richard I et al	Eng	Lance,Swd		Def. by Eng longbow at Crecy
cy	Jenghiz Khan	Mong	Jeng Khan, Sabutai, Kublai, etal	Mong	Tamerlane	Tar-tar	Mong. Bow	Mace, lasso Javelin	Natural Obsolescence
y	Edward I	Eng	Edward III	Eng	Henry V	Eng	Eng Lngbw	Sideams Maul	Devel of Artillery by French, c.1450
y	Foot Soldiers	Swiss	Various	Swiss			Pikehalld	Crossbow	Intro of gunpowder weapons
y	Gonsalvo de Cordova	Sp	Various	Sp	Henry of Navarre Maurice	Fr-Dut.	Arq.;pike	Musket	Obsolescence
y	Gustavus	Swed	Frederick the Great	Pr	Saxe, Napoleon Moore, Wellington	Fr, Fr Engl	Match Musk Mobile Can		Improvement in Weapons, & Napoleonic Division
	Gustavus	Swed	Frederick the Great Gribeauval	Pr Fr	Napoleon	Fr	Smoothbore Cannon		Tech ical Changes. See also #16 below
	Silesian War	Aust	Moore, Morgan	Br-Am	Wellington	Br	Musk, Rif.	Bayonet	Dev. of all-purpose infantry
4	Duc de Broglie	Fr	Napoleon	Fr	Moltke	Pr	Brchlif.	Flint Musk	Machine Gun & High Explosives
	Hutier, et al	Ger	Ludendorff & Gen. Staff	Ger	McNair (in US)	Am	Mach Gun High Expl.	Tank, etc	
	US-R Servs in WWII	US-SR					Various	Various	
F	Mitchel, Trenchard Douhet, Zeppelin	Am-Br Fr-Ger	Harris, Arnold	Am, Am			Lng-Rng Bomber	Various	In process of replacement by ICBM, etc.
	Summerall, et al	Am	Field Art. School	Am			Light & Med Art. piece		
:	Luftwaffe	Ger	Tedder Montgomery	Br Br			Fighter Bomber		

2

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